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PROCEEDINGS

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AMERICAN ACADEMY

OF

ARTS AND SCIENCES.

VOL. XXVIII.

PAPERS READ BEFORE THE ACADEMY.

I.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

A REVISION OF THE ATOMIC WEIGHT OF BARIUM.

FIRST PAPER: THE ANALYSIS OF BARIC BROMIDE.

By Theodore William Richards.

Presented January 11, 1893.

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Introduction.

In the course of a recent determination of the atomic weight of copper,* there was an attempt made to determine the ratio of cupric to baric sulphate; but in the discussion of the result it became evident that the ordinary method of precipitation was far too crude for the desired purpose. Moreover, even had there not been possible errors of a serious nature in the method, the atomic weight of barium was evidently too uncertain to form the basis of any accurate comparison. Hence this attempt was at the time given up,

* These Proceedings, Vol. XXVI. p. 258.

and the plausibility of the single result obtained was ascribed to a chance elimination of opposite errors.

During the early part of this century, a number of chemists have investigated the atomic weight of barium with very widely varying results. The first experiments worthy of mention were made by Berzelius and Klaproth; * but these are now of historical interest only. In 1818 the problem was again undertaken by Berzelius, † who found that from 100.00 parts of anhydrous baric chloride he could obtain 138.07 parts of argentic chloride; whence the atomic weight is readily computed to be 136.8. At the same time he found that the same amount of baric chloride yielded 112.175 parts of baric sulphate, which gives Ba = 135.6.

In 1829 Edward Turner ‡ published a redetermination of the latter ratio, finding the equivalents to be as 100.00 : 112.19. He too weighed the argentic chloride obtainable from a given amount of baric chloride, and arrived at the conclusion that the atomic weight of barium could not be far from 137.45. Two years later T. Thomson § described several attempts to weigh barium as the sulphate, which need not be further discussed. In 1833 Turner ‖ found as a mean of three experiments that 112.03 parts of baric nitrate were required to form 100.00 parts of baric sulphate; a result indicating 137.0 as the atomic weight of barium. Ten years later Salvetat ¶ published a very incomplete account of the quantitative study of the conversion of baric carbonate into sulphate, giving a final result of 136.

Soon after this both Pelouze ** and Marignac †† determined the ratio of baric chloride to metallic silver, the first finding the atomic weight of barium to be 137.3, and the second 137.1. In 1850 Levol ‡‡ reduced auric chloride with sulphurous anhydride, and determined the sulphuric acid which resulted with baric chloride. Recalculated with the recently determined atomic weight of gold, 197.3, §§ these results give 138.3 as the atomic weight of barium.

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The Atomic Weight of Barium. ¶

$O = 16.000.$

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Berzelius, 1811	Ba = 134 to 143
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Comparison of Baric Sulphate with Gold:	
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Marignac, 1848	137.11
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Dumas, 1859	137.00
Ratios including Water of Crystallization:	
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A cursory glance at the list will show a lamentable lack of consistency in the results of even a single method in different hands. The only ratio which seemed capable of yielding approximate results was the ratio of baric chloride to metallic silver, and here the variations in the atomic weight of barium amounted to nearly three tenths of a unit. The question whether the errors were due to mechanical defects of analysis, or to admixture of foreign substances,

* In Clarke's original treatise 137.007 is apparently misprinted for 137.07 (Smithsonian Misc. Coll., Vol. XXVII. p. 63).

became an important subject for consideration; but it is evidently of little use to recalculate such heterogeneous results. The necessity for a careful experimental revision is very apparent. Such a revision would be especially interesting in view of the fact that barium is a member of one of the best marked series of elements known, — a series which might yield important information regarding a possible mathematical relation of the atomic weights. Moreover, the atomic weights of no less than eighteen other elements * have been determined, at one time or another, by reference to baric sulphate. Most of these determinations have been made without the least precaution with regard to the baric chloride occluded in the precipitated sulphate, or on account of the solubility of the sulphate itself; but even if the method had been satisfactory, the determinations could not be considered as anything more than crude approximations, because of our uncertainty regarding the molecular weight of baric sulphate.

These were some of the considerations which prompted the present undertaking. It is not unnatural that the revision should have been begun with the more or less strong belief that the atomic weight of barium could not be far from 137.1; but the progress of the work has completely overthrown this belief, and has indicated a much higher value.

Balance and Weights.

The balance and weights were identical with those used in the latter part of the investigation upon copper,† hence a further description of them is unnecessary. The weights were gently and carefully rubbed, and again standardized with reference to each other; a proceeding which yielded values essentially identical with the two previous standardizations. The first ten-gramme weight was also compared from time to time with the platinum weight which had been carefully standardized in Washington,† in order to test its constancy.

				True Grammes.
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* Li, Be, F, Mg, Si, V, Cr, Ni, Cu, Se, Y, In, (Ba), La, Ce, Di, Au, Tl, Th. Compare L. Meyer and Seubert's "Atomgewichte," p. 165.

† These Proceedings, XXVI. 242.

The second ten-gramme weight, which was much less used, remained quite constant in value.

Throughout the present investigation the method of weighing by tares was universally adopted. A vessel to be weighed was placed upon the left hand scale pan, balanced with common gilded weights, and then replaced by a similar vessel which weighed a few milligrammes less. The exact amount of this extra tare having been determined with the rider, the counterpoise was replaced by the original vessel and the rider removed, in order to determine if the centre point had changed. When only a slight change had taken place, the reading for the counterpoise was compared with the mean of the two readings for the original vessel. In the rare cases when the change exceeded the equivalent of the thirtieth of a milligramme, the vessels were alternately substituted for each other until constancy was reached. A substance to be weighed was of course placed in such a tared vessel, and after substitution the deficiency of the counterpoise was made up with standard weights. The difference between the tares on the left hand scale pan indicated the observed weight in air of the substance taken. It was found convenient to tabulate the results in the following form.

	Common Weights: Right hand pan. Grammes.	Tare: Standard Weights. Left hand pan. Grammes.	Cor. to Standard Weights. Milligrammes.	Corrected Standard Weights. Grammes.	Correction to Vacuum. Milligrammes.	True Weight of Substance taken. Grammes.
Weight of crucible + substance	22.0890	1.80986	—0.05	1.80981		
Weight of crucible alone	20.2797	0.00081	0.00	0.00081		
Weight of substance, cryst. baric bromide	1.8093	1.80905		1.80900	+0.30	1.80930

The lowest right hand figure represents the true weight of the substance taken, if the Sartorius ten-gramme weight is taken as the standard. Reduced to the Washington standard the value becomes 1.80934; but this last correction is in no case applied in the work which follows.

The method used in the case of hygroscopic substances, and most other precautions, are given at length in the paper already quoted. In weighing a crystallized salt it was usually necessary to weigh the crucible while filled with ordinary moist air, hence the counterpoise crucible was exposed to the same conditions.

During the latter part of the investigation the balance was kept in a small room built entirely inside of the main laboratory. The absence of outside windows in the small room caused a notable absence of air currents and rapid changes of temperature, while its glass walls supplied plenty of light.

It is almost needless to state that, while the weights of the apparatus were not reduced to the vacuum standard, — on account of the method of weighing, which rendered such reduction unnecessary, — the weight of every substance used was corrected in the manner shown above for the difference between the weight of air displaced by it and that displaced by the corresponding brass weights. Where the specific gravity of the substance was not already accurately known, it was carefully determined for this purpose.

The Spectroscopic Detection of Calcium and Strontium in the Presence of Barium.

In the course of the search for a typical barium salt it became important to determine how small an amount of calcium and strontium could be detected in the presence of large amounts of barium. The most sensitive method is naturally the spectroscopic one, but no literature giving the degree of sensibility seemed to be at hand.

The first phase of the problem to be investigated was the determination of the amount of calcium and strontium which could be detected in the absence of barium. Hence a standard solution of calcium and strontium was prepared containing 0.8 milligramme of each metal to the cubic centimetre. This solution was successively diluted and tested by means of a well made single prism spectroscope with an adjustable slit. A drop of the solution was supported upan a coil of wire containing 0.018 cubic centimetre, similar to that suggested by Truchot * and so ably used by Gooch and Hart.† No attempt at quantitative analysis was made, the present problem being merely the determination of the limit of visibility.

* Compt. Rend., LXXVIII. 1022.

† Am. Journ. of Sci., [3.] XLII. 448. The writer is much indebted to this paper for valuable hints.

RESULTS.

Dilution.	Weight of Ca. and Sr. vaporized.	Observations.
Solution : Water.	Milligrammes.	
1 : 0	0.014	Brilliant.
1 : 5	0.003	"
1 : 10	0.0014	Very plainly visible.
1 : 20	0.0007	" " "
1 : 40	0.0004	Plainly visible.
1 : 100	0.00014	Both visible.
1 : 200	0.00007	Both scarcely visible.
1 : 400	0.00004	Both invisible.

Hence seven hundred-thousandths of a milligramme is about the limit of visibility under these conditions. It is remarkable that this result should be essentially identical with Bunsen's result obtained by a different method.*

It has long been known† that the best method for detecting small quantities of strontium and calcium in the presence of barium is to evaporate the solution of the chlorides to small bulk, precipitate most of the baric chloride by means of alcohol, and test the filtrate. From this filtrate, by means of two or three repetitions of the fractionation with alcohol, it is possible to eliminate nearly all the barium. It is evident, on the other hand, that if the precipitate is dissolved and reprecipitated several times, all the calcium and strontium must go into the mother liquors. This is one of the most rapid methods of obtaining pure baric chloride; it served for the preparation of the material used in the succeeding experiments.

In the first experiment half a milligramme of calcium was added to the solution of three grammes of very pure baric chloride. Upon the usual fractional treatment a most brilliant calcium spectrum was obtained from the mother liquor. One fifth of a milligramme of calcium in another experiment gave similar results. For a third experiment one fiftieth of a milligramme each of calcium

* Compare Vogel's "Spectralanalyse irdischer Stoffe," 1877, pp. 92, 94.

† Ibid., p. 99.

and strontium was added to five grammes of crystallized baric chloride. The mother liquor from the first precipation by alcohol was evaporated to dryness and extracted with alcohol. Calcium was very evident in the extract, but no trace of strontium. The reason for the apparent absence of the latter metal is to be found in the fact that the mother liquor was evaporated to dryness. To prove this, the same amount of materials were fractionally precipitated three times, and a very evident strontium spectrum was given by the last mother liquor. In the fifth trial, only one two-hundredth of a milligramme of strontium was used. Upon three fractionations no strontium could be detected; but upon dissolving and reprecipitating each of the precipitates once more a faint test for the metal was found in the final mother liquor. This is evidently about the limit so far as strontium is concerned. Calcium may be detected when it is present in quantities much less than the two-hundredth of a milligramme, because of the ready solubility of its chloride in alcohol. The baric chloride used gave no trace of the calcium or strontium lines after most careful fractionation.*

From these experiments it may be concluded that, when a baric salt shows no trace of the allied metals upon the treatment just described, it does not contain a weighable amount of them. Nevertheless, in the work which follows, the purification was usually continued long after the visible traces of strontium and calcium had been eliminated.

The Choice of Material.

It has been already stated that the most satisfactory determinations of the atomic weight of barium have had baric chloride as a starting point. In many respects this substance is well adapted for the purpose; but one serious cause of error must be carefully guarded against in the usual method adopted for its analysis. The well known solubility of argentic chloride influences the accuracy not only of the weight of chloride obtained, but also of the apparent end point of the precipitation after the method of Gay Lussac. Long ago Stas † pointed out this cause of error, and carefully de-

* A trace of sodium was always found in even the purest specimens. It is probable that this trace was derived from the air during the course of fractional treatment necessary to eliminate the barium.

† Aronstein's translation of Stas's Memoir, pp. 46, 56, 59, and especially 295 (Leipzig, 1867).

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During the early part of this century, a number of chemists have investigated the atomic weight of barium with very widely varying results. The first experiments worthy of mention were made by Berzelius and Klaproth; * but these are now of historical interest only. In 1818 the problem was again undertaken by Berzelius, † who found that from 100.00 parts of anhydrous baric chloride he could obtain 138.07 parts of argentic chloride; whence the atomic weight is readily computed to be 136.8. At the same time he found that the same amount of baric chloride yielded 112.175 parts of baric sulphate, which gives Ba = 135.6.

In 1829 Edward Turner ‡ published a redetermination of the latter ratio, finding the equivalents to be as 100.00 : 112.19. He too weighed the argentic chloride obtainable from a given amount of baric chloride, and arrived at the conclusion that the atomic weight of barium could not be far from 137.45. Two years later T. Thomson § described several attempts to weigh barium as the sulphate, which need not be further discussed. In 1833 Turner ‖ found as a mean of three experiments that 112.03 parts of baric nitrate were required to form 100.00 parts of baric sulphate; a result indicating 137.0 as the atomic weight of barium. Ten years later Salvetat ¶ published a very incomplete account of the quantitative study of the conversion of baric carbonate into sulphate, giving a final result of 136.

Soon after this both Pelouze ** and Marignac †† determined the ratio of baric chloride to metallic silver, the first finding the atomic weight of barium to be 137.3, and the second 137.1. In 1850 Levol ‡‡ reduced auric chloride with sulphurous anhydride, and determined the sulphuric acid which resulted with baric chloride. Recalculated with the recently determined atomic weight of gold, 197.3, §§ these results give 138.3 as the atomic weight of barium.

* See Wollaston, Phil. Trans., 1814, p. 20.

† Pogg. Annalen, VIII. 189.

‡ Phil. Transactions, 1829, p. 296.

§ System of Chemistry, 7th Edition, 1831, I. 426.

‖ Phil. Transactions, 1833, p. 538.

¶ Compt. Rend., XVII. 318.

** Ibid., XX. 1047.

†† Liebig's Annalen, 1848, LXVIII. 215.

‡‡ Ann. Chim. Phys., [3.] XXX. 359.

§§ Krüss, 1887; Thorpe and Laurie, 1887; and Mallet, 1889.

In the next year H. Struve* found that 100 parts of baric chloride produced 112.094 parts of baric sulphate, a value which leads to an atomic weight of barium equal to 137.0. T. Andrews † obtained in 1852 the value 137.6, but he gives none of his details. Six years afterwards Marignac ‡ redetermined the ratio of baric chloride to the sulphate, with a result very different from those of his predecessors. In his hands one hundred parts of the former salt yielded only 112.011 parts of the latter, instead of 112.09 or more. In the same investigation he determined the amount of water of crystallization in baric chloride, with results so unsatisfactory that the values calculated from the various ratios varied from 128.5 to over 138, § as well as the ratio of baric chloride to metallic silver. This last determination led to a value for barium only four one-hundredths of a unit higher than his previous work, ten years before. He admits that the substances used in the analysis were not perfectly pure, but assumes that the impurities were not great enough seriously to influence the result. At about the same time Dumas ‖ was also determining the ratio of baric chloride to silver. He fused the salt in a stream of hydrochloric acid gas, but gives no proof that a slight excess of the gas was not absorbed. If this had been the case, of course the observed atomic weight of barium would have been too low. As a matter of fact, he obtained 137.0 for the value of this "apparently variable constant." Below is tabulated a list of the various determinations, grouped according to the processes employed.

The Atomic Weight of Barium. ¶

$O = 16.000.$

Analysis of Baric Carbonate:	
Berzelius, 1811	Ba = 134 to 143
Wollaston and Klaproth, 1814	139.2
Salvetat, 1843	136

* Liebig's Annalen, 1851, LXXX. 204.

† Brit. Assoc. Report, 1852, Part 2, p. 83.

‡ Liebig's Annalen, CVI. 165.

§ See Meyer and Seubert's "Atomgewichte," p. 176.

‖ Liebig's Annalen, CXIII. 22.

¶ The writer is much indebted to the works of Becker, Clarke, Meyer and Seubert, and Ostwald for valuable assistance in preparing this list.

Conversion of Baric Chloride to Sulphate:	
Berzelius, 1818	Ba = 135.6
Turner, 1829	Ba = 135.4
Thomson, 1831	Ba = 136±
Struve, 1851	Ba = 137.0
Marignac, 1858	Ba = 138.5
Conversion of Nitrate into Sulphate:	
Turner, 1833	Ba = 137.0
Comparison of Baric Sulphate with Gold:	
Levol, 1850	138.3
Ratio of Baric Chloride to Argentic Chloride:	
Thomson	Ba = 136±
Berzelius, 1818	Ba = 136.8
Turner, 1829	Ba = 137.4
Marignac, 1858	Ba = 137.1
Ratio of Baric Chloride to Silver:	
Pelouze, 1845	137.28
Marignac, 1848	137.11
Marignac, 1858	137.15
Dumas, 1859	137.00
Ratios including Water of Crystallization:	
Marignac, 1858 (averages)	130.7 to 138.5
Unknown Ratio:	
Andrews, 1852	137.6
Clarke, 1883, selects *	Ba = 137.0
L. Meyer and Seubert, 1883, select	Ba = 137.2
Ostwald, 1885, selects	Ba = 137.04
Van der Plaats, 1886, selects	Ba = 137.1

A cursory glance at the list will show a lamentable lack of consistency in the results of even a single method in different hands. The only ratio which seemed capable of yielding approximate results was the ratio of baric chloride to metallic silver, and here the variations in the atomic weight of barium amounted to nearly three tenths of a unit. The question whether the errors were due to mechanical defects of analysis, or to admixture of foreign substances,

* In Clarke's original treatise 137.007 is apparently misprinted for 137.07 (Smithsonian Misc. Coll., Vol. XXVII. p. 63).

became an important subject for consideration; but it is evidently of little use to recalculate such heterogeneous results. The necessity for a careful experimental revision is very apparent. Such a revision would be especially interesting in view of the fact that barium is a member of one of the best marked series of elements known, — a series which might yield important information regarding a possible mathematical relation of the atomic weights. Moreover, the atomic weights of no less than eighteen other elements * have been determined, at one time or another, by reference to baric sulphate. Most of these determinations have been made without the least precaution with regard to the baric chloride occluded in the precipitated sulphate, or on account of the solubility of the sulphate itself; but even if the method had been satisfactory, the determinations could not be considered as anything more than crude approximations, because of our uncertainty regarding the molecular weight of baric sulphate.

These were some of the considerations which prompted the present undertaking. It is not unnatural that the revision should have been begun with the more or less strong belief that the atomic weight of barium could not be far from 137.1; but the progress of the work has completely overthrown this belief, and has indicated a much higher value.

BALANCE AND WEIGHTS.

The balance and weights were identical with those used in the latter part of the investigation upon copper,† hence a further description of them is unnecessary. The weights were gently and carefully rubbed, and again standardized with reference to each other; a proceeding which yielded values essentially identical with the two previous standardizations. The first ten-gramme weight was also compared from time to time with the platinum weight which had been carefully standardized in Washington,† in order to test its constancy.

				True Grammes.
Oct. 18, 1891	Ten-gramme	weight	=	10.00023
May 16, 1892	"	"	=	10.00023
Nov. 1, 1892	"	"	=	10.00022
Nov. 2, 1892	"	"	=	10.00020

* Li, Be, F, Mg, Si, V, Cr, Ni, Cu, Se, Y, In, (Ba), La, Ce, Di, Au, Tl, Th. Compare L. Meyer and Seubert's "Atomgewichte," p. 165.

† These Proceedings, XXVI. 242.

The second ten-gramme weight, which was much less used, remained quite constant in value.

Throughout the present investigation the method of weighing by tares was universally adopted. A vessel to be weighed was placed upon the left hand scale pan, balanced with common gilded weights, and then replaced by a similar vessel which weighed a few milligrammes less. The exact amount of this extra tare having been determined with the rider, the counterpoise was replaced by the original vessel and the rider removed, in order to determine if the centre point had changed. When only a slight change had taken place, the reading for the counterpoise was compared with the mean of the two readings for the original vessel. In the rare cases when the change exceeded the equivalent of the thirtieth of a milligramme, the vessels were alternately substituted for each other until constancy was reached. A substance to be weighed was of course placed in such a tared vessel, and after substitution the deficiency of the counterpoise was made up with standard weights. The difference between the tares on the left hand scale pan indicated the observed weight in air of the substance taken. It was found convenient to tabulate the results in the following form.

	Common Weights: Right hand pan. Grammes.	Tare: Standard Weights. Left hand pan. Grammes.	Cor. to Standard Weights. Milli-grammes.	Corrected Standard Weights. Grammes.	Correction to Vacuum. Milli-grammes.	True Weight of Substance taken. Grammes.
Weight of crucible + substance	22.0890	1.80986	—0.05	1.80981		
Weight of crucible alone	20.2797	0.00081	0.00	0.00081		
Weight of substance, cryst. baric bromide	1.8093	1.80905		1.80900	+0.30	1.80930

The lowest right hand figure represents the true weight of the substance taken, if the Sartorius ten-gramme weight is taken as the standard. Reduced to the Washington standard the value becomes 1.80934; but this last correction is in no case applied in the work which follows.

The method used in the case of hygroscopic substances, and most other precautions, are given at length in the paper already quoted. In weighing a crystallized salt it was usually necessary to weigh the crucible while filled with ordinary moist air, hence the counterpoise crucible was exposed to the same conditions.

During the latter part of the investigation the balance was kept in a small room built entirely inside of the main laboratory. The absence of outside windows in the small room caused a notable absence of air currents and rapid changes of temperature, while its glass walls supplied plenty of light.

It is almost needless to state that, while the weights of the apparatus were not reduced to the vacuum standard, — on account of the method of weighing, which rendered such reduction unnecessary, — the weight of every substance used was corrected in the manner shown above for the difference between the weight of air displaced by it and that displaced by the corresponding brass weights. Where the specific gravity of the substance was not already accurately known, it was carefully determined for this purpose.

The Spectroscopic Detection of Calcium and Strontium in the Presence of Barium.

In the course of the search for a typical barium salt it became important to determine how small an amount of calcium and strontium could be detected in the presence of large amounts of barium. The most sensitive method is naturally the spectroscopic one, but no literature giving the degree of sensibility seemed to be at hand.

The first phase of the problem to be investigated was the determination of the amount of calcium and strontium which could be detected in the absence of barium. Hence a standard solution of calcium and strontium was prepared containing 0.8 milligramme of each metal to the cubic centimetre. This solution was successively diluted and tested by means of a well made single prism spectroscope with an adjustable slit. A drop of the solution was supported upan a coil of wire containing 0.018 cubic centimetre, similar to that suggested by Truchot* and so ably used by Gooch and Hart.† No attempt at quantitative analysis was made, the present problem being merely the determination of the limit of visibility.

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* Compt. Rend., LXXVIII. 1022.

† Am. Journ. of Sci., [3.] XLII. 448. The writer is much indebted to this paper for valuable hints.

RESULTS.

Dilution.	Weight of Ca. and Sr. vaporized.	Observations.
Solution : Water.	Milligrammes.	
1 : 0	0.014	Brilliant.
1 : 5	0.003	"
1 : 10	0.0014	Very plainly visible.
1 : 20	0.0007	" " "
1 : 40	0.0004	Plainly visible.
1 : 100	0.00014	Both visible.
1 : 200	0.00007	Both scarcely visible.
1 : 400	0.00004	Both invisible.

Hence seven hundred-thousandths of a milligramme is about the limit of visibility under these conditions. It is remarkable that this result should be essentially identical with Bunsen's result obtained by a different method.*

It has long been known† that the best method for detecting small quantities of strontium and calcium in the presence of barium is to evaporate the solution of the chlorides to small bulk, precipitate most of the baric chloride by means of alcohol, and test the filtrate. From this filtrate, by means of two or three repetitions of the fractionation with alcohol, it is possible to eliminate nearly all the barium. It is evident, on the other hand, that if the precipitate is dissolved and reprecipitated several times, all the calcium and strontium must go into the mother liquors. This is one of the most rapid methods of obtaining pure baric chloride; it served for the preparation of the material used in the succeeding experiments.

In the first experiment half a milligramme of calcium was added to the solution of three grammes of very pure baric chloride. Upon the usual fractional treatment a most brilliant calcium spectrum was obtained from the mother liquor. One fifth of a milligramme of calcium in another experiment gave similar results. For a third experiment one fiftieth of a milligramme each of calcium

* Compare Vogel's "Spectralanalyse irdischer Stoffe," 1877, pp. 92, 94.

† Ibid., p. 99.

and strontium was added to five grammes of crystallized baric chloride. The mother liquor from the first precipation by alcohol was evaporated to dryness and extracted with alcohol. Calcium was very evident in the extract, but no trace of strontium. The reason for the apparent absence of the latter metal is to be found in the fact that the mother liquor was evaporated to dryness. To prove this, the same amount of materials were fractionally precipitated three times, and a very evident strontium spectrum was given by the last mother liquor. In the fifth trial, only one two-hundredth of a milligramme of strontium was used. Upon three fractionations no strontium could be detected; but upon dissolving and reprecipitating each of the precipitates once more a faint test for the metal was found in the final mother liquor. This is evidently about the limit so far as strontium is concerned. Calcium may be detected when it is present in quantities much less than the two-hundredth of a milligramme, because of the ready solubility of its chloride in alcohol. The baric chloride used gave no trace of the calcium or strontium lines after most careful fractionation.*

From these experiments it may be concluded that, when a baric salt shows no trace of the allied metals upon the treatment just described, it does not contain a weighable amount of them. Nevertheless, in the work which follows, the purification was usually continued long after the visible traces of strontium and calcium had been eliminated.

The Choice of Material.

It has been already stated that the most satisfactory determinations of the atomic weight of barium have had baric chloride as a starting point. In many respects this substance is well adapted for the purpose; but one serious cause of error must be carefully guarded against in the usual method adopted for its analysis. The well known solubility of argentic chloride influences the accuracy not only of the weight of chloride obtained, but also of the apparent end point of the precipitation after the method of Gay Lussac. Long ago Stas † pointed out this cause of error, and carefully de-

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* A trace of sodium was always found in even the purest specimens. It is probable that this trace was derived from the air during the course of fractional treatment necessary to eliminate the barium.

† Aronstein's translation of Stas's Memoir, pp. 46, 56, 59, and especially 295 (Leipzig, 1867).

scribed his method of procedure, that others might correct his results if they were found to be based upon an incorrect assumption. He added an excess of silver to the chloride to be investigated, and then added the standard solution of a chloride until no more cloudiness was observable. Such a method under ordinary circumstances requires from two to eight milligrammes less of silver to correspond with a given weight of chloride than would be required if the solutions were added in the inverse order.

A number of years afterward * Stas changed his method of procedure, and selected the point half-way between the two extremes as the true end point of the silver reaction. He gave reasons for this change of view, but wholly ignored his previous results. Commentators have laid hardly enough stress upon this important difference between the two series of determinations, although it necessarily involves an error in one series or the other.

Working before even the earliest date of Stas's publication upon this subject, the experimenters upon the atomic weight of barium naturally overlooked the whole question. As nearly as may be guessed from their incomplete accounts, they usually selected the end point obtained by gradually adding argentic nitrate to baric chloride; hence their results cannot be compared with either of Stas's series.

Much time during the past eighteen months has been spent upon this question. The investigation of baric chloride showed that results for the atomic weight of barium varying from 137.35 to 137.50 might easily be obtained from the purest possible salt, according to the interpretation of the data. At last a definite conclusion was reached, and the work is now nearly ready for publication.

The necessity for some other basis for the atomic weight of barium early led to the search for a new starting point. In the course of this search, most of the available baric salts were investigated with regard to their adaptability for the present purpose.

Baric nitrate holds water with great obstinacy, and no certain point of constant weight could be reached by gradually heating it. Besides, the only two methods available for its analysis are extremely unsatisfactory. The conversion into the chloride is rendered very difficult because of the insolubility of both the nitrate and chloride in strong acids. The complete conversion of the

* The Memoir was presented in 1876, according to the title page. Mém. de l'Acad. de Belg., Nouv. Sér., XLIII. See also Van der Plaats, Chem. News, LIV. 52, 88.

nitrate into the sulphate is also difficult because of the well known occlusion of one salt by the other. Moreover, supposing the analysis by either method to have been satisfactorily performed, the data furnished would give only the worst possible foundation for the calculation of the atomic weight of barium.* Many qualitative and quantitative experiments led to the complete rejection of baric nitrate as the material for analysis.

Baric bromate is very readily prepared in a pure state by a few successive crystallizations, and it was hoped that this salt would furnish especially valuable testimony upon the case. But investigation showed that it was impossible to be certain that the crystallized salt did not contain an excess of occluded water. Upon the other hand, it is doubtful if all the water of crystallization can be expelled without a slight decomposition of the salt. Since water is the one impurity most to be dreaded in all such work, baric bromate was rejected, except as a means of obtaining the bromide in a pure state.

The carbonate was next experimented upon; and while the results were more promising than those from the nitrate and bromate, they were less satisfactory and conclusive than those obtained from baric bromide.

The advantages of the use of a bromide for an investigation upon atomic weights are so manifest, and have been so often discussed, as to need no further mention. The current descriptions of the deliquescence and instability of the baric salt alone postponed the consideration of this substance. Investigation showed that misleading statements about the salt have found their way into chemical literature. In reality, the substance is as well adapted for accurate work as baric chloride and most other materials upon which we must rely.

The Properties of Baric Bromide.

Baric bromide crystallizes from aqueous or dilute alcoholic solutions in doubly terminated monoclinic† prisms, which are somewhat hygroscopic, but not deliquescent in ordinary weather.

The crystallized salt contains two molecules of water, together with the slight excess which is usually to be found in such crystals.

* See Ostwald, Allgemein. Chem., I. 23.

† Werther, Journal für prakt. Chem., XCI. 167. Also Von Hauer, same Journal, LXXX. 230. Rammelsberg states that the salt is isomorphous with baric chloride (Pogg. Ann., LV. 237).

Below the temperature of 70° in somewhat moist air, or at the ordinary temperature in perfectly dry air, it loses one of these molecules.* The other one is retained until a temperature of from 100° to 130° is reached, according to the hygroscopic condition of the surrounding air.

The accuracy of the final result for the atomic weight of course depends upon the complete absence of water from the dried salt; hence an especial series of experiments was made to determine the conditions under which the water was completely expelled. Upon heating to redness, the salt is very slightly decomposed; † hence in all cases where a high heat was used the amount of baric hydroxide and baric carbonate formed were determined by means of very dilute standard hydrobromic acid, using phenol phthaleïn and methyl orange respectively as the indicators. The accuracy which it is possible to attain in this process was a great surprise. If a very small amount of pure boiled water is used for the solution of the baric bromide, a deficiency of less than a tenth of a milligramme of bromine in five grammes of the salt is detected with the greatest ease. The correction applied to the weight of the baric bromide was of course always the calculated difference between the weights of the bromine and the hydroxyl, or the carbonic acid, which had taken its place. For example, a deficiency of 0.81 milligramme of hydrobromic acid found by alkalimetry involved a correction of 0.63 milligramme if the alkaline earth had been found in the form of hydroxide, or 0.50 milligramme if it had been found in the form of carbonate. Since baric carbonate is very faintly alkaline to phenol phthaleïn, this correction is not absolutely exact; but its error is an infinitesimal one so far as this work is concerned. It is probable that, if any traces of oxide were formed, they were converted into hydroxide or carbonate before the crucible cooled.

One experiment showed that 1.6 grammes of baric bromide dried at 136° lost 0.4 milligramme on being heated to dull redness. On another occasion, three grammes of baric bromide which had been dried at 200° to constant weight lost 0.50 milligramme upon heat-

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* 2.8688 grammes of crystallized baric bromide lost 0.1547 gramme on heating to constant weight at 70–80°; the residue lost 0.1533 gramme more upon heating to constant weight at 160°. Compare Graham Otto (Michaelis), III. 662.

2.0506 grammes of baric bromide which had been powdered and dried over sulphuric acid to constant weight lost 0.1181 gramme upon drying at 200°.

† Schultze, Jour. f. prakt. Chem., [2.] XXI. 407.

ing to dull redness. Alkalimetry indicated that 0.32 milligramme should be added to the last weight as a correction for the bromine lost; hence the corrected loss was 0.00018 gramme, or 0.006 per cent. A third trial gave the corrected loss of 3.5 grammes of baric bromide between 185° and a dull red heat as 0.00027 gramme, or 0.008 per cent. Again, 3.4 grammes of a less pure specimen of the salt lost 1.2 milligrammes between 200° and dull redness, of which loss eight tenths of a milligramme was accounted for by the baric carbonate found in the dissolved residue. In Experiment 19, about 3.5 grammes of the salt dried at 260° lost 0.04 milligramme on heating to 340°, and 0.27 milligramme more upon subjection to a red heat. In order to prove that the method of desiccation over sulphuric acid was sufficient for the purpose in hand, this specimen was again heated to 400°, and cooled in a vacuum over phosphoric oxide. After the admission of dry air the crucible and contents were found to have *gained* a little less than a twentieth of a milligramme. Since seventeen one-hundredths of a milligramme must be added to the last weight of the salt to correct for the amount of alkali found, it is evident that the salt dried at 340° in the first place could not have retained more than 0.005 per cent of water, which could be expelled at a red heat.

The most severe test of the hygroscopic constancy of baric bromide was obtained by fusion. 17.4841 grammes of baric bromide which had been thoroughly dried at a dull red heat were fused in a platinum crucible, and were found to have lost 4.1 milligrammes during the process. 2.25 cubic centimetres of twentieth normal hydrobromic acid were required to render the solution of the clear cake neutral to phenol phthaleïn, and 0.10 cubic centimetre more made it strongly acid to methyl orange. These figures involve a correction of 7.0 milligrammes to the second weight of baric bromide, making it 17.4870 grammes. The excess of this weight over the first (17.4841) is completely accounted for by the knowledge that a slight indeterminable correction* should have been applied to the earlier one, owing to its previous loss of bromine. The crucible was found to have lost 0.20 milligramme.

Again, two grammes and a half of baric bromide heated to constant weight at 185° lost 2.11 milligrammes on being fused in a double crucible. Of this weight all but 0.17 milligramme (0.007

* From 0.010 to 0.03 per cent.

per cent) was accounted for by the amount of alkali found in the dissolved residue (Experiment 13). In Experiment 4, given below, the bromide was also fused. Although this sample was not weighed at any lower temperature, it is evident from the amount of silver it required that about the same relation must hold true. It is a necessary conclusion from these results that baric bromide loses no more water upon fusion than upon being heated to dull redness without fusion. This constancy of hygroscopic condition gives strong ground for the inference that the ignited salt is wholly free from water, and that the salt dried at 180° contains only about seven thousandths of one per cent of the impurity. Moreover, it is very unlikely that water and baric bromide could remain together at a red heat without mutual decomposition. The question of the absolutely anhydrous condition of most substances must necessarily be a matter of inference, because our methods for the determination of a few tenths of a milligramme of water in the presence of a large amount of other material which may be volatilized are not sufficiently accurate to furnish direct evidence upon this point. Our knowledge regarding baric bromide is hence as full as it is possible to obtain.

The specific gravity of baric bromide has been determined by Schiff.* According to his results the crystallized salt is 3.69 times heavier than the same volume of water, while the anhydrous salt is 4.23 times heavier. Since it is important in reducing weights to the vacuum standard to know the exact values of these physical constants, new determinations were made. Carefully redistilled dry toluol, in which baric bromide is insoluble, was taken as the liquid to be displaced, and two specific gravity bottles were used. The weight of water filling the first bottle was found upon three trials to be 11.4117, 11.4133, and 11.4120 grammes, these values being corrected to 4° for the expansion of the water, but not corrected for the expansion of the glass (24°) nor for the air displaced by the water and weights. An approximate determination of the coefficient of expansion of toluol gave the means of reducing all the weighings with that liquid to the same standard of 24°. Three weighings gave results for the weight of toluol filling the bottle to be 9.8357, 9.8356, and 9.8342 grammes; and 4.4262 grammes of large clear crystals of baric bromide were found to displace 1.0141

* Liebig's Annalen, CVII. 59; also CVIII. 23.

and 1.0126 grammes of toluol at 24°. Hence the specific gravity of crystallized baric bromide at 24° compared with water at 4° is 3.852. No correction is made for the difference in volume of the weights employed.

A sample of baric bromide was dried at 200°, powdered very rapidly, transferred to the specific gravity bottle, and heated for a long time at the softening point of glass. After cooling in a desiccator the weight of the baric salt was found to be 7.6808 grammes. After filling with dry toluol, removing the atmospheric pressure, and shaking as usual, the gain in weight was 8.3878 grammes, as a mean of two closely agreeing trials. Since the volume of the pycnometer had slightly altered during the heating, the bottle was remeasured and found to contain 11.3338 grammes of water at 4° (not corrected for the expansion of the glass), and 9.7685 grammes of toluol at 24°. These data give a result for the specific gravity of anhydrous baric bromide equal to 4.794.

Since the apparatus was not perfect, a new specific gravity bottle was prepared, which gave far more concordant results. With this apparatus 5.7271 grammes of baric bromide, dried for a long time at 200°, were found to displace the same volume as 1.1979 grammes of water at 4°. Here again the salt and toluol were at 24°, and the weights were not corrected for the different volumes of the brass. These figures indicate a specific gravity of 4.781, — not very different from the previous result, but very different from the value obtained by Schiff. The value 4.79 is used in all calculations which follow.

One hundred parts of water dissolve about one hundred parts of anhydrous baric bromide at ordinary temperatures, and nearly one hundred and fifty parts at the boiling point of water.* The salt was found to be much less soluble in alcohol than one would expect from the literature on the subject.

A saturated solution in 87% alcohol contains only about six per cent of baric bromide at the ordinary temperature. In absolute alcohol the salt is even less soluble. These facts had an important bearing on the methods of purification.

* See Graham Otto, *loc. cit.* Also recent experiments here.

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* Liebig's Annalen, CVII. 59; also CVIII. 23.

and 1.0126 grammes of toluol at 24°. Hence the specific gravity of crystallized baric bromide at 24° compared with water at 4° is 3.852. No correction is made for the difference in volume of the weights employed.

A sample of baric bromide was dried at 200°, powdered very rapidly, transferred to the specific gravity bottle, and heated for a long time at the softening point of glass. After cooling in a desiccator the weight of the baric salt was found to be 7.6808 grammes. After filling with dry toluol, removing the atmospheric pressure, and shaking as usual, the gain in weight was 8.3878 grammes, as a mean of two closely agreeing trials. Since the volume of the pycnometer had slightly altered during the heating, the bottle was remeasured and found to contain 11.3338 grammes of water at 4° (not corrected for the expansion of the glass), and 9.7685 grammes of toluol at 24°. These data give a result for the specific gravity of anhydrous baric bromide equal to 4.794.

Since the apparatus was not perfect, a new specific gravity bottle was prepared, which gave far more concordant results. With this apparatus 5.7271 grammes of baric bromide, dried for a long time at 200°, were found to displace the same volume as 1.1979 grammes of water at 4°. Here again the salt and toluol were at 24°, and the weights were not corrected for the different volumes of the brass. These figures indicate a specific gravity of 4.781, — not very different from the previous result, but very different from the value obtained by Schiff. The value 4.79 is used in all calculations which follow.

One hundred parts of water dissolve about one hundred parts of anhydrous baric bromide at ordinary temperatures, and nearly one hundred and fifty parts at the boiling point of water.* The salt was found to be much less soluble in alcohol than one would expect from the literature on the subject.

A saturated solution in 87% alcohol contains only about six per cent of baric bromide at the ordinary temperature. In absolute alcohol the salt is even less soluble. These facts had an important bearing on the methods of purification.

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* See Graham Otto, *loc. cit.* Also recent experiments here.

Preparation of Materials.

Baric Bromide. — This substance was prepared in five distinct ways, with the intention of determining whether the salt is capable of being obtained in a perfectly typical state.

In the first place pure baric carbonate was prepared from pure baric nitrate. To make this latter substance the baric nitrate of commerce ("purissimum"), containing traces of strontium, calcium, potassium, and sodium, was recrystallized seven times from boiling water by cooling. Baric nitrate is the most convenient starting point for the preparation of a typical barium salt, since its solubility rapidly diminishes with the temperature, and is so much less than that of the calcium and strontium salts. Even after the second recrystallization the alcoholic fractionally precipitated extract of a large amount of the mother liquor, which had been evaporated with excess of pure hydrochloric acid, showed no trace of calcium or strontium bands in the spectroscope. The pure salt, which had been recrystallized seven times, was dissolved in a large platinum vessel in water which had been distilled in a platinum retort, and was treated with an excess of pure ammonia water which had also never come in contact with glass or porcelain. Into this perfectly clear solution was led a current of pure carbon dioxide, prepared by the action of pure sulphuric acid on sodic hydric carbonate. It was found impossible to free such carbonic acid from a trace of sodium, shown by conducting the gas into a lamp flame, as long as the sodic hydric carbonate was dry. After this last substance had been submerged under two inches of water, the gas evolved was easily obtained in a perfectly pure state by passing it through a sufficient number of washing bottles containing at first a weak solution of sodic hydric carbonate and finally pure water.

The pure baric carbonate was washed with hot distilled water until twenty five cubic centimetres of the wash water showed no trace of ammonia upon the addition of Nessler's reagent. The last washing was with water which had been distilled in platinum. The snow-white preparation was dried and gently ignited over a spirit lamp in a platinum dish.

From this baric carbonate three different preparations of baric bromide were made, by dissolving it in two different samples of hydrobromic acid and varying other conditions. The first sample of acid was prepared from perfectly pure bromine. This had been

made by the distillation of a mixture of potassic permanganate with a dilute solution of an excess of potassic bromide and pure sulphuric acid. Before being converted into hydrobromic acid the bromine was redistilled after solution in potassic bromide and agitation with zincic oxide.* The bromine was in the first place poured into pure baric hydroxide, and, after the separation of the greater part of the baric bromate, was converted into hydrobromic acid by pure sulphuric acid. The baric hydroxide is easily freed from the usual trace of chlorine by five recrystallizations from hot water; in this case the substance was crystallized nine times. The sulphuric acid had been redistilled three times, the first and last portions being rejected.

The dilute hydrobromic acid, containing a small amount of free bromine set free by the remaining baric bromate, was distilled. The colored first portion of the distillate was thrown away, and a portion of the second fraction was analyzed to prove its purity. 1.82471 grammes (in vacuum) of silver,† dissolved with all possible care in the purest nitric acid, yielded 3.17641 grammes (in vacuum) of argentic bromide upon precipitation with a slight excess of the acid. Hence the percentage of silver in the precipitate must have been 57.446, a result which is essentially identical with Stas's result 57.445.

In this hydrobromic acid a portion of the pure baric carbonate was dissolved, and the solution was evaporated with a slight excess of baric carbonate to the point of crystallization. The crystals were dried over the water bath and ignited at a dull red heat over a Berzelius lamp for half an hour. The filtered solution was allowed to stand until neutral to phenol phthaleïn, showing that all the small amount of baric hydroxide formed upon heating had been eliminated, and after filtration was evaporated. As before, the mother liquor was rejected; the crystals were washed twice with pure redistilled alcohol and dried in the air. These crystals formed the first preparation, designated I.a, and served for the two preliminary analyses.

The second preparation of baric bromide was made from a similar specimen of baric carbonate by its solution in hydrobromic acid, prepared essentially in the manner described in the work upon the atomic weight of copper.‡ To test the purity of this acid 1.60376

* Stas, Mém. Acad. Belg., N. S., XLIII., Part II, p. 38.

† See page 22 of this paper.

‡ These Proceedings, XXV. 197.

grammes (in vacuum) of silver were dissolved and precipitated by a slight excess of the acid, yielding 2.79184 grammes (in vacuum) of argentic bromide. Hence the percentage of silver in the precipitate was 57.444 (according to Stas, 57.445). The baric bromide made from this acid was recrystallized, ignited at dull redness, dissolved, allowed to stand exposed to the air, filtered, crystallized, dehydrated, and fused at bright redness by means of an alcohol lamp. Finally, after solution, filtration, slight acidification with hydrobromic acid, and two successive crystallizations, the small amount of substance which remained was used for Analyses 3 and 4 (Preparation No. I.b). The salt contained in the last mother liquor was fused into an absolutely clear limpid liquid, dissolved, faintly acidified, filtered, and recrystallized, the crystals being washed with alcohol, and finally analyzed under the designation No. I.c (Analysis 5). It is needless to say that in all the concluding operations platinum vessels and the purest water alone were used.

The second general method used in the preparation of baric bromide was based upon the decomposition of baric bromate. This salt was obtained in a very pure state by repeated recrystallization of the bromate remaining from the first preparation of hydrobromic acid by the method described above. In the course of the recrystallization it was noted that the glittering hard crystals emit brilliant flashes of bluish light upon being rubbed between the surfaces of moistened glass apparatus. This phenomenon takes place when there is no conceivable trace of organic matter present, and may be noticed even in the daylight. The substance was gradually raised to a dull red heat by means of a Berzelius lamp, no emission of light being noticed during its decomposition. The resultant baric bromide was dissolved, filtered, crystallized twice, washed with alcohol, and dried. After fusion over the spirit lamp the substance was redissolved, filtered, acidified with hydrobromic acid, and finally crystallized twice from water. Each yield of crystals was washed four times with the purest alcohol. In the first mother liquor a notable trace of sodium was found by the usual spectroscopic treatment, but no trace of calcium or strontium. The purest crystals were divided by yet another crystallization into three fractions, which we may call II.a, II.b, and II.c. The last was obtained by the evaporation of all the mother liquor decanted from the first two.

The third method used for the preparation of baric bromide

adopted baric nitrate as its starting point. This salt, which had been recrystallized ten times, was dissolved in hot water and treated with the calculated amount of the purest obtainable potassic hydrate in a platinum bottle. The resulting baric hydrate was recrystallized ten times from hot water, without being removed from the bottle; but the spectroscope still showed noticeable traces of potassium upon the usual fractional treatment. The hydroxide was then precipitated three times successively from aqueous solution by means of pure alcohol, the precipitate being washed each time with alcohol, with the aid of the filter pump. Even the second mother liquor showed no trace of potassium to the most careful scrutiny.

The pure baric hydrate thus prepared was dissolved in pure water in the platinum bottle, boiled for some time to drive off the alcohol, transferred to a Bohemian flask, and saturated with pure bromine. This substance had been prepared as described on page 17, with the additional treatment of solution in pure calcic bromide and several distillations. The mixture of baric bromide and bromate was evaporated, powdered, and gradually raised to fusion in a platinum vessel. The mass was gray before fusion and pale green afterwards. The greenish cake was dissolved in water, filtered, acidified, crystallized, dried and fused; and then this same round of operations was again repeated. The last pure white cake of baric bromide was dissolved, the solution filtered, and after being very faintly acidified with hydrobromic acid was again crystallized. The final crystals were washed four times with alcohol, and allowed to dry in the air. In the table below (page 27) they are designated No. III. (Analyses 10, 11).

Since baric hydroxide is so easily recrystallized it was hoped that a pure preparation might be obtained directly in this way from the baryta of commerce. It has been already said that five recrystallizations remove the chlorine; five more remove the last traces of calcium. When, however, after seventeen recrystallizations, the large amount of strontium present did not seem to be considerably diminished, this method was abandoned as a hopeless one.

A long series of qualitative and quantitative experiments upon the fractional precipitation of baric carbonate by the action of small amounts of carbon dioxide upon baryta water showed that this process also was utterly unfitted for the complete separation of strontium from barium, and accordingly this method was abandoned. The description and data of these experiments would require much

room, and, since the work was not fruitful, they may well be omitted.

Because of all these unsatisfactory results the baric hydrate was converted directly into baric bromide and bromate by the addition of pure bromine similar to that used in the preparation of Sample III. The large amount of bromide filtered off from the bromate was half crystallized out by boiling down the mother liquor in a platinum dish, treating with alcohol, and cooling. The mother liquor from these crystals contained most of the strontium. The solid was dissolved, boiled down, treated with alcohol and cooled; and the new crystals were washed four times with alcohol. After repeating this round of operations once again, the mother liquor showed no trace of strontium.* The pure crystals yielded a faintly brownish mass upon fusion, and this in turn left a brownish precipitate upon solution. The clear filtered liquid was boiled down and treated with alcohol just as described above. The crystals were again fused, and again subjected to the same succession of operations. For the last time the crystals were raised to a dull red heat by means of a spirit lamp, and the residue was dissolved in the purest water in a platinum dish, allowed to stand exposed to the air until neutral, filtered, recrystallized twice more, and washed with the purest alcohol. The resulting material was designated IV.a (Analyses 13, 14, 15). The last mother liquors were evaporated, and yielded IV.b (Analysis 12). Only about fifteen grammes of such pure material were obtained from a kilogramme of the baric hydroxide which served as the starting point. The earlier mother liquors containing strontium were used for the preparation of pure hydrobromic acid.

The fifth method for the preparation of baric bromide was the most complicated of all. A large amount of a solution of baric chloride ("purissimum") was allowed to stand for eighteen hours after the addition of a little pure baric hydrate and carbonate. To the filtered and slightly acidified liquid was added enough potassic chromate to precipitate about half the barium, the potassic chromate having been previously purified by continued shaking with a little baric chloride and hydrochloric acid, and by subsequent filtration. The large mass of baric chromate was washed by decantation

* This method of freeing baric from strontic bromide suggests P. E. Browning's work with amyl alcohol, published since the experiment recorded above was completed. (Am. Journ. Sci., [3.] XLIV. 459.)

with much water until no chlorine was to be found in the filtrate, and was almost wholly decomposed by strong nitric acid. The solution was diluted and shaken with the excess of baric chromate for a long time. Upon the neutralization of the nitric acid in the clear yellow filtrate with pure sodic carbonate, the baric chromate was largely recovered, and after a thorough washing it was again dissolved in nitric acid, and the baric nitrate was repeatedly crystallized until it was wholly colorless and neutral. By means of gradually increasing heat baric oxide was formed from this nitrate, the ignition taking place in a platinum crucible, and continuing until long after the frothing had ceased. The crucible itself lost several milligrammes during the process. The brownish residue was dissolved in water, and the clear colorless liquid was filtered from the brown precipitate. The baric hydroxide was neutralized with pure hydrobromic acid,* and the baric bromide was passed many times through the often repeated round of fusion, solution, filtration, and crystallization, until the fused cake was perfectly clear and colorless. After being faintly acidified with hydrobromic acid, the pure salt was crystallized, washed, and dried as usual. This specimen, which had been growing smaller and smaller in amount during the manifold processes to which it had been subjected, was enough only for one analysis (No. 16) and was designated V.

Out of the baric bromate which remained from the fourth preparation two other specimens of baric bromide were prepared. The only point in which this preparation differed from the second method was the fact of the strong acidification of the bromide with hydrobromic acid just before the final series of crystallizations. The crystallization was then continued until the mother liquors proved to be absolutely neutral. The purest crystals were designated VI.a; the mother liquor from them yielded VI.b (Analyses 17,18, 19).

It seemed probable that, if all these preparations gave about the same value for the molecular weight of baric bromide, they would fix this constant with comparative certainty. It is doubtful if the substance can be prepared in a state of absolute purity. Stas found it impossible to prepare any of his haloid salts in such a state,† a small amount of silica always remaining. The attempt was made

* This acid was from the same sample as that employed in making specimens I.b and I.c.

† See Stas's "Untersuchungen," Aronstein, pp. 269, 279, 346.

to eliminate the silica from the preparations described above by repeated ignition and fusion, and the exclusive use of platinum vessels; but it cannot be proved that the attempt was wholly successful. However, the salt was at least as pure as our usual standards of reference.

Silver. — Pure silver was prepared in the first place by the reduction of pure argentic chloride by pure milk sugar, after the well known method recommended by Stas. A full description of the details is to be found in the account of the analysis of cupric bromide;* indeed, some of the silver used in the present work was a portion of one of the large buttons made in 1890. Only in one particular was the mode of preparation modified: the silver was not heated with fused potassic hydroxide. Two or three buttons of the silver were fused with borax and sodic carbonate on hard-wood charcoal; this treatment made no essential change in its quantitative relations. The silver contained no oxygen, and gave very qualitative and quantitative evidence of purity.†

All of the silver which has been thus far described was fused in the flame of ordinary illuminating gas. Since a strongly reducing flame was used, it was presumed that no silver sulphide was formed. Nevertheless, it was deemed advisable to prepare a sample of the metal which should be free from even the possibility of reproach. Ordinary hydrogen is apt to be quite as impure as illuminating gas, hence as little adapted for the present purpose. For this reason, pure hydrogen was made from pure hydrochloric acid by the action of zinc which was quite free from arsenic. The gas was driven through water, much potassic hydrate, through a tube containing beads moistened with argentic nitrate, and finally through potassic permanganate, into a gas-holder over water, where it remained for some time. It was burnt in an oxyhydrogen blowpipe provided with a complete platinum tip, and served for the fusion of the silver used in Experiment 19. For the support of the metal during its fusion a cupel of sugar charcoal had been made from pure sugar by the sole use of an alcohol lamp as the source of heat. The silver itself was made from the pure silver first described by dissolving it in nitric acid and electrolytically depositing it with the aid of two Bunsen cells,‡ two plates of the same

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* These Proceedings, XXV. 197, 198.

† Ibid.; also this paper, pages 17, 28, 29.

‡ J. L. Hoskyns Abrahall, Journ. Ch. Soc. Proc., 1892, p. 660.

metal serving as electrodes. This method for the preparation of pure silver is a very satisfactory one. Since the silver was allowed to cool in an atmosphere of hydrogen, it could have contained no oxygen. The agreement of Experiment 19 with the others is satisfactory proof that the amount of sulphur contained in the first samples of silver must have been infinitesimal, if appreciable at all.

Other Materials. — The methods used for the preparation of pure water, pure nitric and sulphuric acids, and pure sodic carbonate, have been discussed at length in a previous paper.* Precautions taken with regard to carbon dioxide, hydrobromic acid, and many other substances, are to be found under earlier heads. Alcohol was purified for the present investigation by repeated distillation in apparatus wholly free from cork or rubber connections. In some cases a platinum still was used.

The large mass of platinum used in the first experiments was kindly loaned by Professor Cooke, but subsequently a quantity was purchased especially for the work. The methods used in freeing the surface of these vessels from iron are described in the fourth paper upon the revision of the atomic weight of copper.†

The Method of Analysis.

Thus far it has been found possible to determine accurately only the ratio of baric bromide to silver and argentic bromide. Unfortunately no accurate method for the direct determination of the amount of metal present is known to exist; hence a complete analysis is impossible.

The usual scheme of operations was very simple. The baric bromide, after having been pulverized in an agate mortar, was heated for a long time at 200–400°; it was then gradually raised to dull redness, and maintained for some time at that temperature. Repeated heating sometimes caused a very slight loss, due to increased decomposition; but more usually the weight remained constant. The drying oven was a large porcelain crucible, and at first illuminating gas was used as the source of heat. Afterwards, when a faint trace of cloudiness found in the solution of the baric bromide was traced to the formation of baric sulphate from the sulphur in the illuminating gas, an alcohol lamp was used exclusively. In Analyses 3, 4, 15, 16, and 17 the amount of this insoluble residue was determined, and appropriate correction was made. In

* These Proceedings, XXVI. 245–249. † Ibid., 249.

Analyses 6, 7, 9, and 12 the cloudiness of the solution was so slight as to be inessential, while in Analyses 2, 5, 8, 10, 11, 14, 18, and 19 the neutral solution of the baric bromide was absolutely clear.

The method of weighing was precisely similar to that employed with anhydrous cupric sulphate.* Afterwards the salt was dissolved in the purest boiled water, and the traces of baric hydrate and carbonate present were determined in the manner which has been already described.† The appropriate correction having been applied to the last weight of the baric bromide, the solution was diluted and transferred to a glass-stoppered Erlenmeyer flask. To this was added about the corresponding amount of accurately weighed silver, which had been dissolved in the purest nitric acid with all possible precautions.‡ The argentic nitrate solution had been freed from the lower oxides of nitrogen by long heating at 100° in an inclined flask, and both solutions were quite cold at the moment of precipitation. Daylight was carefully excluded during this operation, as well as during the subsequent ones. After violent shaking, the precipitate was allowed to settle, and the excess of bromine or silver was determined by titration. It is well known that even here there is a slight difference between the end points, although the possible error is very much less than with the chloride. In the table below the mean between the two extremes is recorded; and in general the observations and method of treatment corresponded essentially with those since published for the late J. L. Hoskyns Abrahall in the account of his interesting work on the atomic weight of boron,§ to which the reader is referred. The end point was always determined by titrating backward and forward until there could be no doubt of its accuracy, a cubic centimetre of each of the solutions employed corresponding to one milligramme of silver. In the final experiments the solutions were weighed as well as measured. For these experiments, a dark room was built, and provided with an arrangement, essentially similar to that described by Stas,‖ for condensing a beam of yellow light upon the surface of the liquid in the flask, leaving the precipitate in darkness.

In some cases the baric bromide was poured into the argentic

* These Proceedings, XXVI. 243, 252.

† This paper, page 12.

‡ These Proceedings, XXV. 198.

§ Edited by T. Ewan and P. J. Hartog, J. Chem. Soc. Proc., 1892, p. 663.

‖ Aronstein's translation, page 45.

nitrate,* instead of *vice versa*. This difference of procedure seemed to increase the distance between the two end points, but not to influence the final averaged result.†

In most cases a slight excess of hydrobromic acid was added before filtering, but the amount recorded in the table always represents that which was equivalent to the end point of the reaction. In Experiments 3, 6, 12, 14, and 15, where argentic nitrate was added in excess before filtration, the total amount of silver given in the table signifies the sum of the amount of silver weighed out and that which was added to attain the end point. The extra silver is of course not counted. The agreement of Analyses 14 and 15 with 18 and 19 is sufficient to show the accuracy of both methods. The clear yellow precipitate was washed by decantation until the filtrate became wholly neutral, and was collected and weighed on a Gooch crucible. The first filtrates were always passed through the crucible several times, for fear that a trace of asbestos might have been carried away. One of the absolutely clear filtrates containing a trace of hydrobromic acid gave no sign of a reaction for silver after evaporation to small bulk.

In a number of experiments, modifications in the methods described above were introduced. The most important change was the one adopted in Analyses 2, 8, 14, and 18. In these four cases the baric bromide was not heated at all, but the crystallized salt was dissolved directly in water.‡ In order to determine the amount of anhydrous salt which must have been present in these specimens, parallel determinations of the water of crystallization were made with the greatest care upon precisely similar samples. The agreement of these results with the others is the best possible proof of the accuracy of the alkalimetric correction applied to those determinations in which the substance had been ignited.

In Experiments 4 and 13 the baric bromide was fused. In Analyses 6, 14, 15, 18, and 19 the argentic bromide was fused, and the weight of the fused salt is recorded in the final table. In the first case the substance had been slightly darkened by exposure to light; hence a little pure bromine vapor was added to the glass tube in which the fusion was conducted, and the bromide gained 0.07 milligramme during the process. The other results are tabulated below.

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* E. g. Exp. 14, 15, 16.

† Compare Stas, Mém. Acad. Belg., XLIII., Introduction.

‡ This procedure was suggested by a part of Marignac's work on the chloride (*loc. cit.*).

No. of Analysis.	Weight of Argentic Bromide before Fusion.	Loss of Argentic Bromide on Fusion.
	Grammes.	Grammes.
14	7.17411	0.00018
15	4.4583	0.00001
18	3.63751	0.00013
19	4.37867	0.00000

In Experiment 11 a hard glass tube with small rubber stoppers was employed for the ignition of the baric bromide, but it was attacked by the salt and gained 0.10 milligramme during the heating. This gain corresponds to a loss of about the same weight of bromine, assuming all the barium which combined with the glass to have been converted to the oxide. For this reason the amount of hydrobromic acid recorded in the seventh column of the final table is about 0.12 cubic centimetre too large. In calculating the corrected weights of baric bromide, silver, and argentic bromide, allowance is made for all these facts. Because of the complication of all these little corrections, the glass tube was abandoned, and the platinum crucible was again used.

Data and Results.

The first column of the final Table of Data gives the number of the experiment. The second column contains the weight of the crystallized baric bromide, while the third contains the observed weight of the ignited baric bromide. After this is recorded the number of cubic centimetres of standard hydrobromic acid (of which one litre corresponded to a gramme of silver) required to restore the small amount of bromine lost during ignition. This quantity is divided into two parts, the upper one corresponding to baric hydroxide, and the lower to baric carbonate. Multiplying the upper figure in this column by $\frac{63}{108}$ milligramme, and the lower figure by $\frac{50}{108}$ milligramme, and adding the two products to the weight given in column III., we obtain the corrected weight of the baric bromide which is recorded in the fifth column. The sixth column gives the total weight of silver taken; the seventh, the number of cubic centimetres of the same hydrobromic acid necessary to titrate back to the mean end point; and the eighth, the weight

TABLE OF DATA. — ALL WEIGHTS ARE CORRECTED TO THE VACUUM STANDARD.

I. Number of Analysis.	II. Weight of Crystallised Baric Bromide.	III. Observed Weight of Anhydrous Baric Bromide.	IV. HBr Solution to Neutral Alkali.	V. Corrected Weight of Anhydrous Baric Bromide.	VI. Total Weight of Silver.	VII. HBr Solution to titrate back.	VIII. Weight of Silver corresponding to $BaBr_2$.	IX. Total Weight of Argentic Bromide.	X. Argentic Bromide corresponding to $BaBr_2$.	XI. Sample of Baric Bromide used.
	Grammes.	Grammes.	Cm.³	Grammes.	Grammes.	Cm.³	Grammes.	Grammes.	Grammes.	
1	2.56714	2.28760	....	....	1.66314	2.40	1.66074	2.89444	2.89026	I.a
2	3.89534	Not ignited.	0	3.4712	2.52554	5.35	2.52019	4.39566	4.38635	I.a
3	....	3.80860 *	1.90 2.50	3.81086	....	0.30	....	4.81740	4.81688	I.b
4	....	2.19830 *	1.65 0.25	2.1994	1.59832	1.45	1.59687	....	....	I.b
5	....	2.35954	0.12 0.22	2.35971	1.71618	2.90	1.71323	2.98735	2.98230	I.c
6	3.30433	2.94178	0.32 0.22	2.94207	2.13889	3.05	2.13584	3.72340	3.71809	II.a
7	1.80930	1.61177	0.16 0.11	1.61191	1.17100	0.30	1.17020	....	....	II.b
8	2.36427	Not ignited.	0.00	2.10633	1.53056	1.35	1.52921	2.66426	2.66191	II.b
9	....	2.91650	0.32 0.26	2.91682	2.11840	1.00	2.11740	3.68789	3.68615	II.c
10	2.66363	2.37226	0.33 0.90	2.37290	1.72298	0.22	1.72276	2.99906	2.99868	III.
11	2.07483	1.84804	0.14 0.00	1.84822†	1.34328	1.65 †	1.34175†	2.33797	2.33530†	III.
12	....	1.9088	1.40 0.00	1.9046	....	0.37	....	2.40798	2.40733	IV.b
13	2.75591	2.45417	3.08 0.30	2.45611	....	....	....	....	....	IV.a
14	6.35791	Not ignited.	0.00	5.66647	4.12090	7.30	4.11360	7.1739	7.1612	IV.a
15	3.95705 *	3.52610 *	0.35 0.35	3.5267	2.56100	0.90	2.56010	4.4583	4.4567	IV.a
16	4.3442 *	4.3161 *	0.00 1.75	4.3169	3.13550	1.20	3.13430	....	....	V.
17	3.78040 *	3.36557 *	0.15 1.50	3.36635	2.44567	1.32	2.44385	....	...	VI.b
18	3.22971	Not ignited.	0.00	2.87743	....	0.54	....	3.63738	3.63644	VI.a
19	3.88750	3.46330	0.03 0.32	3.46347	2.51529	1.14	2.51415	4.37867	4.37669	VI.a

* Corrected for small amount of baric sulphate (or silica) found on solution. † See page 26.

N. B. — Two weights (the argentic bromide of Analysis 4 and the silver of Analysis 18) are omitted from this table, as they were known to be in error. It might have been well to omit the whole of the twelfth experiment for the same reason. The other blanks were never filled.

of the silver corrected by subtracting from the weight given in column VI. the amount of silver corresponding to the quantity of acid given in column VII. In the same way, the ninth and tenth columns contain respectively the total and the corrected weight of argentic bromide. Hence the weights actually used in the calculation of the results are those recorded in columns V., VIII., and X.

The discussion of the results is simplified by reducing all the amounts of baric bromide to the basis of 100.000 parts of silver, and the corresponding quantity, 174.080 parts, of argentic bromide. The water of crystallization is included in the following table only because the calculation of Analyses 2, 8, 14, and 18 depends upon the knowledge of its amount. The great variations noticeable in the results for the water of crystallization are due to the varying circumstances attendant upon the crystallization, to the fineness of the powder, and to the hygroscopic condition of the air at the time of weighing the crystals. Hence for the present purpose it was possible to compare only like samples which had been weighed out under like conditions. Analyses 13 and 15 show that in this way perfect constancy can be reached. This part of the work has of course no other bearing upon the atomic weight of barium.

The first two experiments were merely preliminary, and are not included in the final average. Most of the variations evident in the earlier experiments were undoubtedly due to unfavorable conditions existing in the Laboratory during the year 1891–92. In the autumn of the latter year the Laboratory was completely and most admirably remodelled, through the kindness of the Corporation of the University, and the last seven experiments were performed under conditions as favorable as could be desired.

The presence of any of the most likely metallic impurities — strontium, calcium, potassium, or sodium — would tend to lower the observed values recorded in the third and fourth columns of the Table of Results, and hence the atomic weight of barium. Chlorine would lower and iodine would raise the values given in the third column, but neither would have much effect on those given in the fourth column. The best possible proof of the freedom of the preparations from these two impurities, as well as of the purity of the silver, is to be found in the series of results giving the per cent of silver in silver bromide, tabulated in the fifth column of the Table of Results.* The presence of water in the ignited baric bromide would naturally tend to raise the figures given in both the third

* See also these Proceedings, XXV. 212.

TABLE OF RESULTS.

Number of Analysis.	Salt employed.	Parts of Baric Bromide corresponding to 100.000 Parts Silver.	Parts of Baric Bromide corresponding to 174.080 Parts Argentic Bromide.	Per Cent of Silver in AgBr.	Water of Crystallization in Baric Bromide.
1	I a	137.746	137.788	57.460	10.889
2	I.a	137.736	137.760	57.455	
3	I.b		137.728		
4	I.b	137.732			
5	I.c	137.735	137.739	57.447	
6	II.a	137.748	137.748	57.445	10.964
7	II.b	137.747			10.910
8	II.b	137.740	137.747	57.448	
9	II.c	137.755	137.748	57.442	
10	III.	137.738	137.752	57.451	10.915
11	III.	137.747	137.772	57.455	10.922
12	IV.b		137.726		
13	IV.a				10.878
14	IV.a	137.750	137.745	57.443	
15	IV.a	137.756	137.754	57.445	10.875
16	V.	137.731			10.885
17	VI.b	137.748			10.953
18	VI.a		137.745		
19	VI.a	137.759	137.758	57.445	
Aver., omitting Exp. 1 and 2.		137.745	137.747	57.448	
Average of last seven Exp.		137.749	137.751	57.444	
Stas found				57.445	

and fourth columns: the arguments indicating the absence of this insidious impurity were discussed at length in the first part of the paper.*

The agreement between the individual results is as close as could reasonably be expected, when one considers the small amounts of material used in some cases. It may be concluded, then, that a hundred parts of silver correspond to about 137.747 parts of anhydrous baric bromide, no matter what may be the method used for its preparation. If the salt contains an impurity, it is strangely constant in amount.

The Atomic Weight of Barium.

From the results which have just been given, the atomic weight of barium is very readily computed. In the following table are given the values corresponding to the three standards at present in use.

From the Ratio of Silver to Baric Bromide.

If Silver = 107.93, and Bromine = 79.955, Barium = **137.426**
If Silver = 107.66, and Bromine = 79.755, Barium = 137.083
If Silver = 107.12, (Oxygen = 15.88,) Barium = 136.396

Greatest variations from the mean, $\begin{cases} +\ 0.030. \\ -\ 0.040. \end{cases}$

From the Ratio of Argentic Bromide to Baric Bromide.

If Argentic Bromide = 187.885, Barium = **137.431**
If Argentic Bromide = 187.415, Barium = 137.089
If Argentic Bromide = 186.476, Barium = 136.401
Greatest variation from the mean, ±0.054.

It is not very difficult to explain the reason for the difference between this new value, 137.43, and the old one, 137.10. The incomplete knowledge regarding the end point of chlorine reaction in 1858 is probably responsible for a part of the difference, and a portion more may possibly be explained by the impurities which were assumed to be inessential. But it has already been said that a discussion of the results of thirty-five years ago can be of little value. The only true solution of the question is the experimental one. In the near future, I hope to continue the investigation which is herewith commenced, as well as to begin a similar research upon strontium and calcium.

Cambridge, December 24, 1892.

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* This paper, page 12.

II.

CONTRIBUTIONS FROM THE CRYPTOGAMIC LABORATORY OF HARVARD UNIVERSITY.

XIX. — ON THE DEVELOPMENT OF THE SPERMOGONIUM OF CÆOMA NITENS (Schw.).

By Herbert Maule Richards.

Presented by W. G. Farlow, January 11, 1893.

While the mature condition of the spermogonium of *Cæoma nitens* has been described and figured in more than one instance, there has been little written about its development. The general impression seems to have been that the hyphæ of the fungus, which ramify through the tissues of the leaf, penetrate the walls of the epidermal cells when spermogonia are about to be produced, and that by subsequent growth the spermogonia are formed in the cavities of the epidermal cells so penetrated.* It is exactly this question as to whether the spermogonium actually arises within, and not perhaps between, the epidermal cells, that is the subject of the following remarks. It is more than a year since Professor Farlow suggested to me the advisability of settling this disputed point, but until the present spring I did not have a chance of carrying out the suggestion. In the spring of 1891 I collected in the vicinity of Cambridge a considerable amount of material of the spermogonia of *Cæoma nitens* on *Rubus villosus*. It was gathered in the latter part of April, and was at that time in very young condition, having scarcely begun to show itself on the surface of the leaves. The material was killed in hot picric acid, and was then successively treated with the usual grades of alcohol, so that it was in good condition for examination. At first, free hand sections were wholly used, but afterwards sections cut in paraffin with a microtome were also employed for confirming certain points that could only be settled by serial sections.

* Burrill, in "The Prairie Farmer," Vol. LVII. p. 762, 1885.

It will be well before speaking of the spermogonia themselves to give a brief description of the hyphæ of the fungus as they appear in the host plant. Before the spermogonia have begun to develop, a section of the affected leaf of the Rubus shows the presence of hyphæ, which ramify through its tissues, without, however, producing any very great distortion in the cells. The hyphæ are of a pretty uniform diameter, and, while at first almost simple, later become considerably branched. They do not seem to traverse the cells themselves to any great extent, if at all, making their way rather between adjacent cells and in the air spaces of the leaf. They do, however, send into the cells curious haustoria which present a very characteristic appearance (Figs. 5 and 9) already figured by Newcomb and Galloway.* At the places where these processes pass through the cell walls they are contracted to a very much smaller diameter than the ordinary hyphæ, but inside the cavity of the cell they become very much expanded, and often curiously knotted. A few characteristic forms have been figured (Fig. 9, *a*, *b*, *c*). The haustoria were more noticeable in the material which had been collected later in the season than in that gathered before the spermogonia were to be seen.

In the region immediately below the epidermis, the hyphæ are very much more thickly massed than in other portions of the leaf, having forced their way in between the epidermal cells and the parenchyma beneath. In this locality, and also to some extent elsewhere, it may be demonstrated by proper staining that the hyphæ are septate, especially after the formation of the spermogonia. In fresh material the contents of the hyphæ are largely hyaline, only occasionally showing a finely granular appearance, and many vacuoles are to be seen. As has already been said, the hyphæ themselves do not excite any marked morbid growth in the tissues of the leaf, but in the immediate neighborhood of the spermogonia there is a very considerable distortion. In leaves that are at all badly affected by the fungus, the chlorophyll very generally changes its color, becoming yellowish or brownish, so that the infected portions are very noticeable on the growing plant. In such cases the whole contents of the epidermal cells, as well as the chlorophyll grains, have disintegrated more or less, particularly in the immediate neighborhood of the spermogonia.

The first indication of the formation of a spermogonium is seen

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* Journal of Mycology, Vol. VI. p. 106, Pl. VI., 1891.

in the activity of the hyphæ which lie immediately below the epidermis. Certain of these hyphæ are seen to send out processes which grow out towards the surface of the leaf. These outgrowths push their way between the epidermal cells, but do not at this early stage enter them, soon becoming, however, multicellular by the formation of frequent cross septa (Figs. 1, 2). At first the cells which surround the developing spermogonium are but little affected, the rapidly growing hyphæ merely splitting the wall at the middle lamella. The space between the cell walls, thus separated and forced apart, affords a cavity in which the hyphæ may grow. The hyphal threads now increase very rapidly in number, both by division and by the sending up of new outgrowths from the hyphæ beneath, so that the parted walls of the adjoining epidermal cells are very much pushed outwards to make room for the developing spermogonium (Fig. 3). At the same time, these hyphæ, which were at first very irregularly arranged, show a tendency to place themselves in parallel rows, and their contents begin to assume a more granular appearance than those of the ordinary vegetative hyphæ. Both of these conditions become more marked as the spermogonium matures.

As the spermogonium continues to increase in size, it exerts more and more pressure on the walls of the cells which confine it, and having distended them outwards as far as possible finally ruptures them (Fig. 4, *a*). The rupture takes place from the atrophy of the walls, which have by this time become very much weakened by pressure. The hyphæ are now free to grow into, and eventually fill, the larger space afforded by the union of the cavities of the surrounding cells. The remnants of the ruptured walls are apparently soon absorbed or hidden by the growing hyphæ, for in stages of the spermogonium not a great deal more advanced than this they are very hard to distinguish. It is usually a long time, however, before all traces of the separating wall are lost, as will be noticed in Figure 4, *b*, for even in this much later stage indications of the wall may still be seen in a slight protuberance, which extends downwards into the cavity of the spermogonium. The time in the development of the spermogonium at which the rupture takes place is not at all constant; in some cases where the mass of hyphæ was very small, it was seen to have already broken through the walls. After the hyphæ have made their way into the larger cavity, their parallel arrangement becomes more conspicuous than before, and as the hyphæ continue to multiply in number and increase in size a

morbid growth starts up in the cells surrounding them. The cavity in which the spermogonium is forming enlarges very much as the hyphæ continue to grow and fill it. This enlargement takes place chiefly in a vertical direction, although there is a considerable lateral expansion as well, as the spermogonium rises above the surrounding epidermis. The shape finally assumed is that of an inverted truncated cone, but at times the spermogonia are almost pyriform. No differentiation of the hyphæ into anything like a peridium is seen, the cell walls of the host plant remaining as the only covering that the spermogonium has even to maturity. Eventually the upper wall disappears, being apparently absorbed and finally broken through by the hyphæ beneath, which are thus exposed to the air. The abnormal growth that affects the cells in which the spermogonium is developing is also taken up by the epidermal cells which immediately surround it. These increase somewhat in diameter, but chiefly extend themselves in height, and, owing to the excessive development of the top of the spermogonium, are often somewhat bent upon themselves. On one side they cling fast to the spermogonium wall, on the other they are rounded off, rising considerably above the other epidermal cells (Figs. 5, 6). These cells serve the purpose of supporting the spermogonium, the ring of them completely surrounding it, as is shown in the figure of the transverse horizontal section (Fig. 7). Usually a second row of cells, outside of the supporting cells, are also modified to some extent, and serve in turn to support the inner row. In some cases it was observed that a third row of cells was also somewhat distorted, and in leaves which were very thickly beset with spermogonia scarcely an epidermal cell was not to some extent swollen.

The further development of the spermogonium is not of especial interest in this connection. As it matures, it gradually takes on the characteristic orange color of these organs, and the hyphæ are seen to become slightly swollen at the tips. From the tips of the hyphæ the spermatia are abstricted, to be finally liberated by the breaking away of the enveloping cell wall (Fig. 8). It is not infrequently the case that a large number of spermatia are formed before being set free (Fig. 5). The color of the spermogonium is due, as in other Uredineæ, to the bright orange oil-like particles which are found in the hyphæ. In addition to the oil globules, the hyphæ are filled with finely granular matter which also has an orange tinge. The contents of the surrounding epidermal cells are greatly altered, varying from an orange to a brownish yellow

color, depending upon their proximity to the spermogonia, and in cases where many spermogonia have developed on a leaf the whole organ takes on a yellowish color.

From the observations described above, it seems impossible to consider the cavity in which the spermogonium develops as originating from a single cell, being rather from the junction of several cells. In other words, the spermogonium starts in the first place as an outgrowth *between*, and not *in*, the epidermal cells of the host, soon however by pressure breaking through and absorbing the confining walls, and making its way into the cavities of the surrounding cells. As the absorption of these walls may take place very early in the development of the spermogonium, before the mass of hyphæ has reached any considerable size, one might be easily deceived into thinking that the spermogonium was forming in the cavity of a single epidermal cell, which had been, perhaps, enlarged somewhat by a morbid growth excited by the fungus. It is also possible that one of the haustoria, already referred to, might have been mistaken for the very earliest stage in the growth of a spermogonium. The question might arise as to whether the young stages herein described were not in reality tangential sections of much older ones, but in the light of the evidence afforded both by the sequence of stages observed and by carefully cut series of sections it is sufficient to say that such could not have been the case.

As regards comparison with other spermogonia, a few words may be of interest. The spermogonium of *Cæoma nitens* is not, it is true, exactly comparable with the typical flask-shaped form usually found in connection with other Uredineæ, as it is much more superficial, the growth starting immediately beneath the epidermis and extending outwards towards the surface of the leaf, while in the case of the spermogonium of *Æcidium berberidis*, for instance, the spermogonium originates in the parenchyma of the leaf, and remains very largely buried in it even to maturity. On the other hand; the spermogonium of which the form found on Anemone is a type is seen to be even more superficial than that of *Cæoma nitens*, the very much flattened cone-shaped masses being located immediately below the cuticula. The course of the development as well as the ultimate result is simpler in *Cæoma nitens* than in *Æcidium berberidis*, as the hyphæ merely remain in parallel rows, and have for their only covering the cell walls of the host plant, while in the case of the flask-shaped spermogonium there is a definite false peridium formed by a more or less distinct matting together of the peripheral hyphæ.

In the former case apparently all of the hyphæ bear spermatia, in the latter case only those in the interior of the flask-shaped mass are fertile. The hyphal portion of the spermogonium of *Cæoma nitens* corresponds then most nearly to the central part of such a spermogonium as is seen in the case of *Æcidium berberidis.*

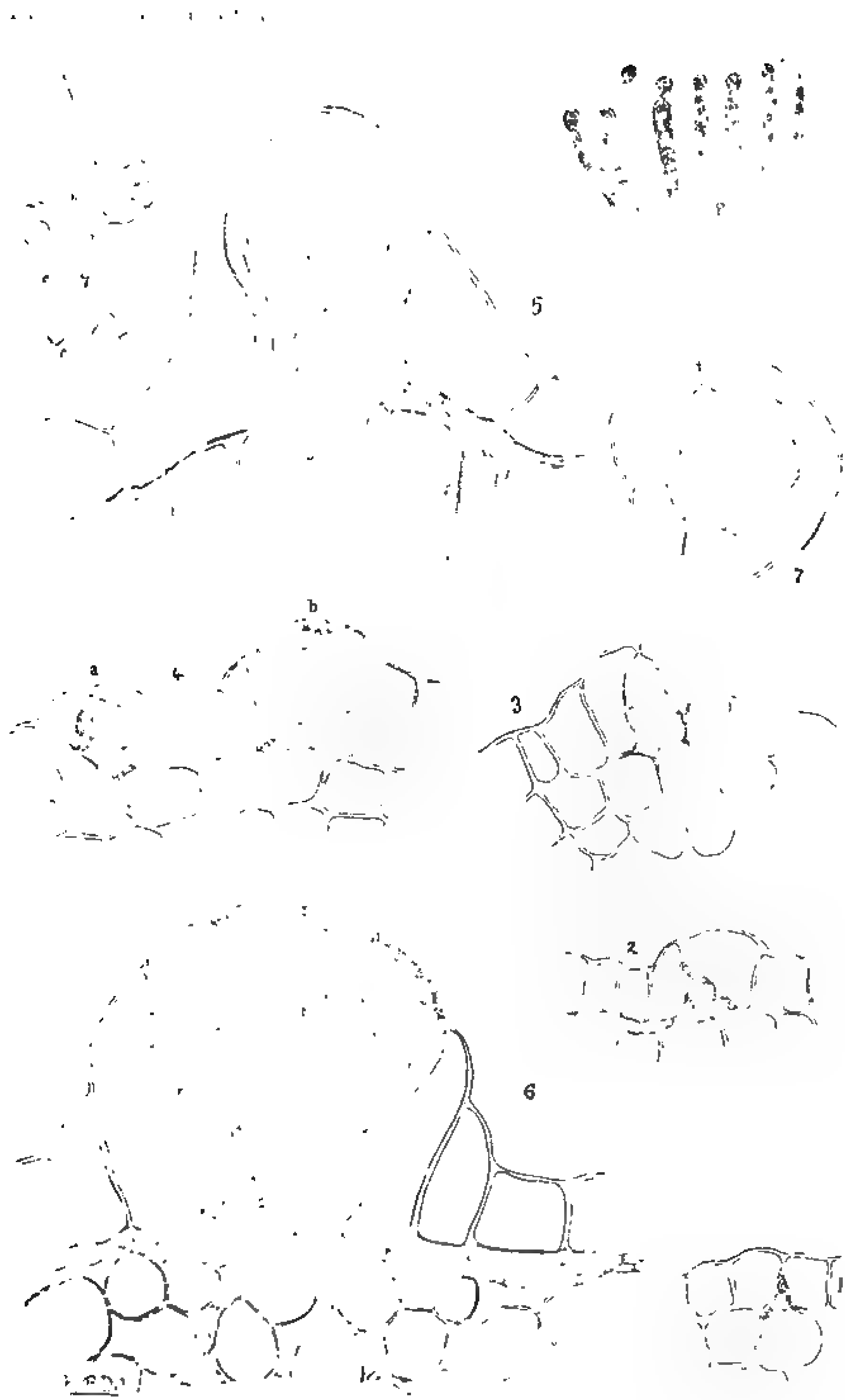
In the above work a very convenient and satisfactory stain was found in methylene blue. This was used in a one per cent solution, and the sections were stained on the slide. The sections were first considerably overstained, and then, by treatment with acetic acid, were decolorized to just the point desired. The process of decolorization was watched under the microscope and stopped when enough of the stain had been washed out. The acetic acid having been thoroughly gotten rid of, the sections were then mounted in glycerine according to the usual method. By means of this decolorization some differentiation in the staining was brought out, for the acid has a tendency to extract the color from the cells of the host more quickly than from the hyphæ of the parasite, so that in a section of the leaf the latter show out much more plainly than they would otherwise have done. In the case of sections cut in paraffin the acetic acid also served to swell up the somewhat shrunken tissues to a more natural appearance.

EXPLANATION OF FIGURES.

Fig. 1. A very early stage of the spermogonium.
" 2. A slightly more advanced condition, but before the hyphæ have any definite arrangement.
" 3. Showing the splitting apart of the walls of the epidermal cells, and also the parallel arrangement of the hyphæ in the young spermogonium.
" 4. *a*, showing the rupture of the walls by the hyphæ. *b*, a more advanced stage, where there is only a trace of the dividing wall left.
" 5. A mature spermogonium with only one row of supporting cells.
" 6. A mature spermogonium with the normal two rows of supporting cells.
" 7. Horizontal section of mature spermogonium.
" 8. Hyphæ from spermogonium showing formation of spermatia.
" 9. *a*, *b*, *c*. Haustoria.

Figures 1 to 7 × 425 diameters; Figures 7 and 8 × 650 diameters. Figures 1 to 4 drawn from sections of alcoholic material; Figures 5 to 9, from fresh specimens. All figures drawn with Abbe camera.

June, 1892.



5
7
a
b
4
3
2
6

INVESTIGATIONS ON LIGHT AND HEAT, MADE AND PUBLISHED WHOLLY OR IN PART WITH APPROPRIATION FROM THE RUMFORD FUND.

III.

ON A THERMO-ELECTRIC METHOD OF STUDYING CYLINDER CONDENSATION IN STEAM-ENGINES.*

BY EDWIN H. HALL.

Presented January 11, 1893.

BEFORE the time of James Watt the steam in an engine cylinder was condensed, and so gotten rid of, after it had done its work, by pouring cold water directly upon or into the cylinder. So, whenever steam was admitted for a new stroke, a great part of it was condensed in the act of reheating the cylinder wall; whence the term *cylinder condensation*. Watt invented and brought into use the independent condenser, by means of which the steam is removed from the cylinder with comparatively little cooling of the latter. It is believed, however, that even now cylinder condensation wastes a good deal of steam in common engines, whether condensing or non-condensing. The commonly accepted theory is, that during the exhaust the wall of the cylinder, to a certain depth from the steam space, or a layer of water upon the cylinder wall, becomes cooled by the evaporation which accompanies exhaustion, and that the incoming steam finds this wall, or the layer of water upon it, considerably cooler than itself. It is believed that some part of the steam which is thus condensed upon the cylinder wall during admission is recovered during the later part of the *forward* stroke by re-evaporation, but that a considerable amount, sometimes

* An informal account of much that is contained in this article was given before the Academy in May, 1891. A similar account was given before the American Institute of Electrical Engineers in New York, May 20, 1891, and was printed in the Transactions of that Society.

25% of all the steam used by the engine, is not recovered in this way, and only reappears during the *back* stroke, when it is worse than useless, as it increases the back pressure which the returning piston must overcome. Engineers have been led to this theory by a study of indicator diagrams, that is, diagrams made automatically while the engine is in operation, and recording the steam pressure within the cylinder at every point of the forward and backward stroke (see Figure 5). Such diagrams commonly show the weight of *steam* in either end of a cylinder to increase in the latter part of each stroke, as the piston moves forward after the admission valve is closed, but the greatest weight of steam shown by the indicator diagram at any part of the stroke is less than the weight of steam *and water* passing through the cylinder at each stroke. Accordingly, it is argued that a considerable part of that which comes from the boiler as steam goes through the cylinder as water, at least during that part of the stroke when it would, as steam, be of service.

But there have not been wanting some to maintain that the observed, or apparent, effect, as shown by the indicator diagram, is too large for the alleged cause. In January, 1889, Mr. Dickerson of New York, a distinguished patent lawyer, now dead, speaking before the Electric Club of New York, advanced the proposition that the peculiar character of the indicator diagram, which is supposed to show cylinder condensation and subsequent re-evaporation, is really due to leakage of steam past the engine valves, past the exhaust valve in the early part of the stroke, past the admission valve during the latter part of the stroke, the whole effect being to make the *expansion curve,* so called, of the diagram too steep at the beginning, and too nearly horizontal at the end. He made the statement that the steamers in the waters about New York City will make four or five miles an hour with the valve between the boiler and the cylinder closed. I do not know how accurate that statement was, but I have never seen it contradicted. Mr. Dickerson's argument excited my interest, and I cast about for some method of studying the problem of so called cylinder condensation, not, as engineers had done and are still doing, by means of the indicator diagram, but through the cylinder wall by means more familiar to the physicist than to the mechanical engineer. I wished to determine by actual trial how great are the fluctuations of temperature occurring during a complete forward and back stroke of an engine at a given depth of metal from the surface touched by the steam.

For this purpose I naturally had recourse to a thermo-electric device.*

The engine belonging to the Harvard Physical Laboratory, with which my experiments were made, is a Kendall and Roberts of 10-inch cylinder and 15-inch stroke, provided with an ordinary Myer's valve and cut-off. It is jacketed by an air space about 2 cm. wide.

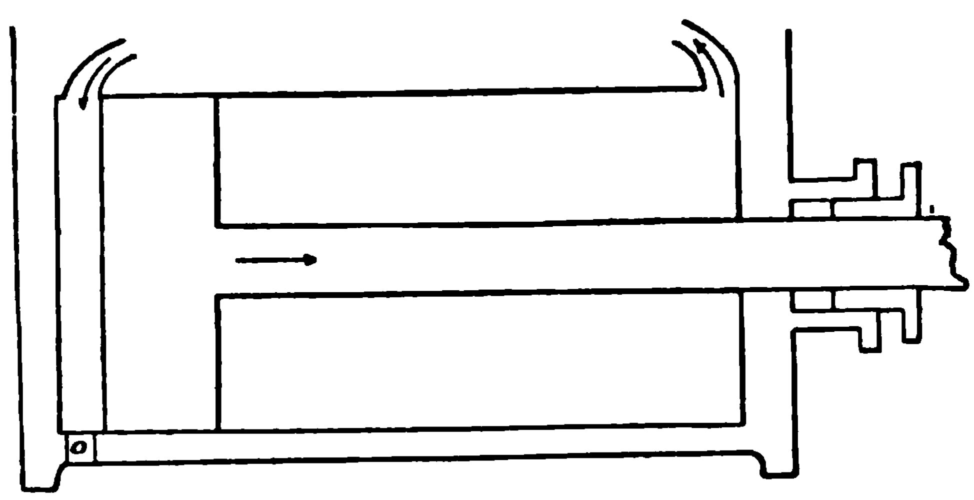


Fig. 1.

Figure 1 shows a horizontal longitudinal section of the cylinder, with the piston at the beginning of its forward stroke. The cylinder wall, about 2 cm. in thickness, is pierced at *o* for making connection with an indicator. Into this hole, which is about 2 cm. wide, I screwed a plug represented accurately enough by Figure 2. On the inner end of this plug was soldered a cover of

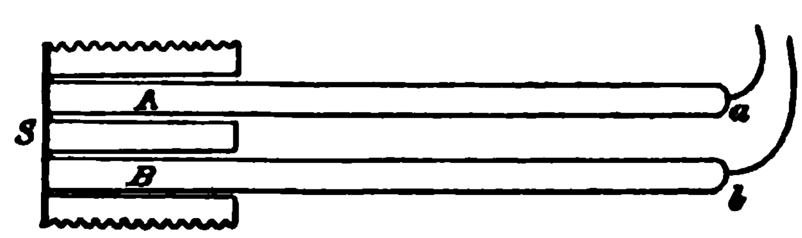


Fig. 2.

thin steel, *S*. Through two holes in the plug, and insulated from it by glass tubes, two rods extended to touch the steel cover, one, *A*, of antimony, the other, *B*, of bismuth. To the outer end of *A*, at *a*, was soldered a copper wire; to the outer end of *B*, at *b*, was soldered a similar wire. These two wires lead to a ballistic galvanometer, but at one point the electric circuit was broken, except

* A letter received from Mr. Bryan Donkin, Jr., of London, the well known engine builder, after the first account of my experiments was published, showed me that he had been before me in making experiments in the same general manner, but with small bulb thermometers in mercury cisterns instead of thermopiles. The *Bulletin de Société de Mulhouse* for 1890 contains some account of his work. My results appear to be not discordant with those which he obtained.

when, at any desired part of the stroke, it was closed for a short time by the revolving crank of the engine. With this apparatus there should be a current, and therefore an effect upon the galvanometer, at closure of the circuit, so long as the two inner ends of the antimony and bismuth bars, which press against the steel, are at a different temperature from the outer ends, which are placed side by side in a pot of melted paraffin or hot oil. But when, on the other hand, there is no effect on the galvanometer at closure, one may, if proper precautions have been taken, conclude that the temperature at that surface of the steel which is touched by the antimony and bismuth, to determine which is the object of the experiment, is the same as that of the heated liquid surrounding the ends *a* and *b*, which a thermometer at once makes known.

This represents one stage of the investigation, but as I gradually became convinced that considerable fluctuations of temperature really occurred at measurable depths of the cylinder wall, I saw that a better considered thermopile than the one at first used was needed. I must discard the steel, the thermal conductivity of which might differ considerably from that of the cast-iron composing the cylinder wall, and must replace the antimony and bismuth by something not very different from cast-iron in thermal conductivity, for it is evident that the temperature existing at any moment at the surface of contact of the iron and the metal outside it may depend greatly upon the conductivity of this second metal. Moreover, this surface of contact should be of considerable breadth, and the contact very perfect; in short, everything should be done to make the surface of contact resemble in all its conditions, as nearly as might be consistently with the object of the experiment, the surface of contact of two strata of iron within the actual cylinder wall. Accordingly, I made the plug and the cover, which now was fastened by four small steel screws to the inner end of the plug (see Figure 3), from the same bar of cast-iron, — not ordinary cast-iron, which would be too brittle for the thin cover, but cast gun-iron of density 7.18, which I found by experiment to have a thermal conductivity not very different from that of ordinary Southern cast-iron of density 7.06. In place of the antimony and bismuth bars I now used a single cylinder of cast nickel of density 8.08, the thermal conductivity of which I have found by experiment to be very nearly the same as that of the cast gun-iron at 115° or 120° Centigrade. The specific heat of nickel is about the same as that of iron.

Notwithstanding the great similarity of cast-iron and cast nickel in many respects, they make a powerful thermo-electric couple, so that nickel appeared to be of all substances the one best fitted for my purpose. The hole bored in the iron to receive the nickel cylinder was about 0.65 cm. in diameter. The cylinder itself was about 0.025 cm. less in diameter, so that when wrapped with a single layer of ordinary printing paper it would fit rather snugly in the hole. The cast-iron plug with its cap in place was about 2.2 cm. long, and the nickel cylinder projected very slightly beyond the outer end of the plug.

The inner end of the iron plug, the inner end of the nickel core, and that surface of the iron cap which was to press against them, were all worked with great care to a plane polished surface. The cap and the nickel core were then soldered together in the following manner. That part of the cap surface which was to meet the nickel was thinly tinned with ordinary solder and then the cap was screwed firmly into place upon the plug. That end of the nickel which was to meet the iron was also tinned, and then this core, wrapped, save at the ends, by a single layer of paper, was thrust into the hole in the plug. The plug with its contents was then heated very hot, and while hot was placed in a vise between blocks of wood, which by the action of the vise pressed the nickel core and the iron cap so close together that the layer of solder left between them was, according to my measurements, less than 0.002 cm. thick. Then, after cooling, the screws holding the cap in place were drawn out, and cap and core were carefully removed from the plug. The excess of solder which had been pressed from between them, and which had gathered about the base of the core, was then carefully turned off in a lathe with a brass tool. The core was then wrapped with fresh paper and put back in place, the cap being carefully screwed on. Red lead was used around the screws holding the cap, but I depended mainly upon the perfection of the contact between cap and plug to prevent leakage at this joint.*

* In some of the experiments this joint was not perfectly tight, for water was sometimes seen to come out past the core, *N*, before the plug became hot. Generally upon such occasions the leaking appeared to cease when the plug became hot. The fact probably is that the joint continued to leak slightly, but leaked dry steam, the temperature at the outer end of the plug being about 110° C., and at the inner end considerably higher. Both experiment and reason indicate that the effect of such leakage upon the temperatures observed was slight.

Three plugs were thus completed, the caps being respectively 0.051 cm., 0.101 cm., and 0.203 cm. thick. All the iron parts were from one bar, and all the nickel parts were from one bar.

From the nickel core of each plug when in use extended a slender bar of nickel about 15 cm. long, made from the same piece as the core, and from the outer end of the iron plug extended a similar bar of iron made from the same piece as the plug. The bars were not rigidly fastened to the nickel core and the iron plug, but were held by friction in holes bored to receive their ends. The outer ends, *i* and *n*, Figure 3, extended through a plug of hard rubber, *P*, screwed into the thickened wall, *WW*, of a vessel containing melted paraffin, and copper wires soldered to these ends led back through the hard-rubber plug toward the galvanometer, which was about 60 m. distant. To facilitate adjustments the central hole of the

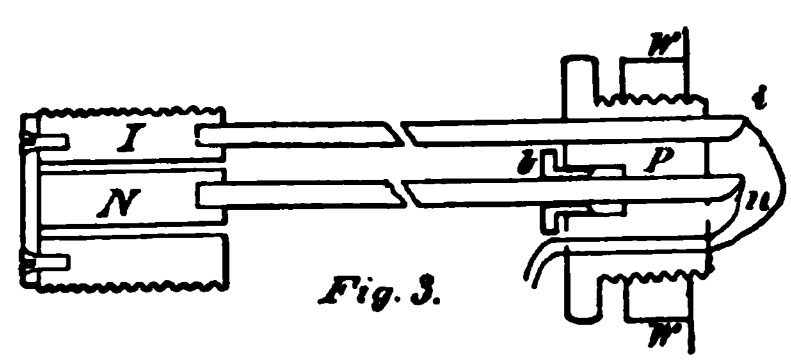


Fig. 3.

hard-rubber plug was made somewhat too large for the nickel connecting bar reaching through it, and a stuffing-box, *b*, was depended on to prevent leakage past this bar. The bulb of a thermometer hung near the junctions *i* and *n* in the melted paraffin, which was heated by a lamp placed below and was stirred by a mechanism driven by the engine.

The key by means of which the electric circuit could be closed for a short part of each stroke required some thought in its evolution, and will be described with detail, although no doubt it might be improved.

At one stage in my experiments I tried making contact by means of a fork-shaped spring of brass, which revolved with the engine crank, and at one part of the stroke bestrode a gap in the circuit, rubbing with each prong upon brass. A certain amount of thermoelectric force was to be expected at each of the two rubbing points of contact, but I had hoped that the two forces would counteract each other sufficiently for my purpose. In this I was disappointed, and I afterwards endeavored to avoid rubbing at the point of closure of the circuit. The key finally used was essentially like

that shown in Figure 4, in which *B* is a block of hard wood about 14 cm. long on the upper curved edge, 6 cm. thick, and 5 cm. wide. The brass spring *S* fastened to the top of the block is connected by means of the wire *l* with the galvanometer. The brass spring *S′* also fastened to the top of the block, is connected by means of the wire *l′* with one of the junctions *i* or *n* in the pot of melted paraffin. The two springs do not at present touch each other, but will do so at *P*, as soon as *S′* is lifted by the lever *LL*, which is pivoted at *a*, and will be struck at *E* by the cam *K* on the engine crank. The lever *LL* works in a narrow slot sawed in the block *B*. To prevent short circuiting through the body of the engine this lever

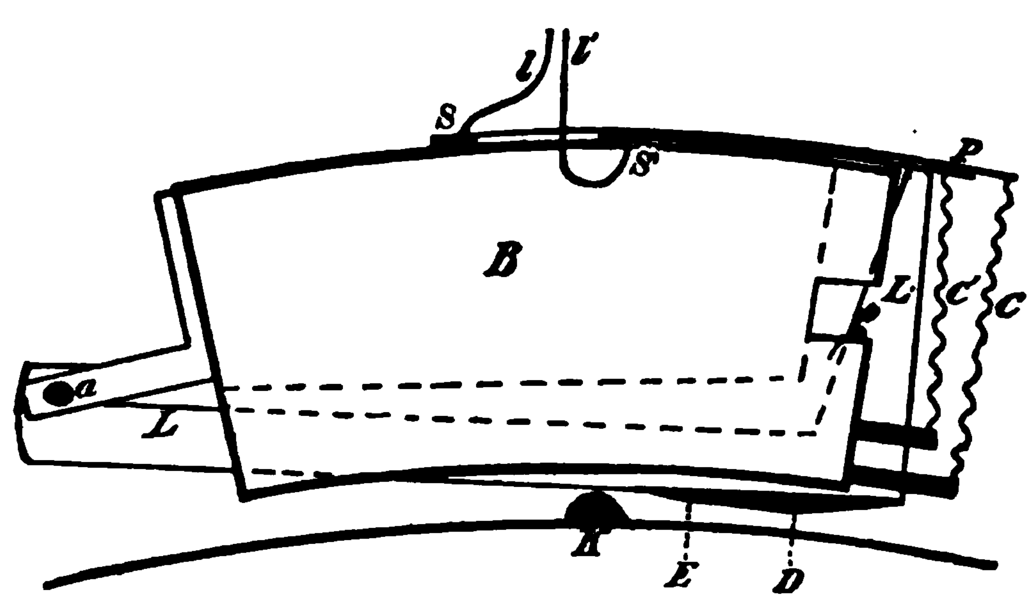


Fig. 4.

is tipped with hard rubber where it touches the spring *S′*. The electromotive force which one has to deal with in this experiment is so small that a mere touch of *S′* against *S* is not sufficient. Contact must be maintained for a short time, and for this purpose the lever *LL* is so shaped that the cam *K* rubs against it all the way from *E* to *D*, about one sixtieth of a revolution, one sixtieth of a second in my experiments. To prevent illegitimate contacts or illegitimate breaks between *S* and *S′*, each of these strips is controlled by two stiff spiral springs, which are indicated by *C* for *S*, and by *C′* for *S′*. The motion of *S* is, moreover, limited by stops, not shown in the figure, placed above and below at the end. The lever *LL* is made of thin sheet brass in order that its momentum may not be troublesome, but the part *ED*, along which contact with *K* endures, is reinforced by a narrow strip of iron soldered on. A pin, *p*, keeps *LL* in contact with *S′* when both are at rest, and prevents the lever from dropping so far as to be struck too hard by *K*.

Investigations on Light and Heat, made and published wholly or in part with Appropriation from the Rumford Fund.

III.

ON A THERMO-ELECTRIC METHOD OF STUDYING CYLINDER CONDENSATION IN STEAM-ENGINES.*

By Edwin H. Hall.

Presented January 11, 1893.

Before the time of James Watt the steam in an engine cylinder was condensed, and so gotten rid of, after it had done its work, by pouring cold water directly upon or into the cylinder. So, whenever steam was admitted for a new stroke, a great part of it was condensed in the act of reheating the cylinder wall; whence the term *cylinder condensation*. Watt invented and brought into use the independent condenser, by means of which the steam is removed from the cylinder with comparatively little cooling of the latter. It is believed, however, that even now cylinder condensation wastes a good deal of steam in common engines, whether condensing or non-condensing. The commonly accepted theory is, that during the exhaust the wall of the cylinder, to a certain depth from the steam space, or a layer of water upon the cylinder wall, becomes cooled by the evaporation which accompanies exhaustion, and that the incoming steam finds this wall, or the layer of water upon it, considerably cooler than itself. It is believed that some part of the steam which is thus condensed upon the cylinder wall during admission is recovered during the later part of the *forward* stroke by re-evaporation, but that a considerable amount, sometimes

* An informal account of much that is contained in this article was given before the Academy in May, 1891. A similar account was given before the American Institute of Electrical Engineers in New York, May 20, 1891, and was printed in the Transactions of that Society.

25% of all the steam used by the engine, is not recovered in this way, and only reappears during the *back* stroke, when it is worse than useless, as it increases the back pressure which the returning piston must overcome. Engineers have been led to this theory by a study of indicator diagrams, that is, diagrams made automatically while the engine is in operation, and recording the steam pressure within the cylinder at every point of the forward and backward stroke (see Figure 5). Such diagrams commonly show the weight of *steam* in either end of a cylinder to increase in the latter part of each stroke, as the piston moves forward after the admission valve is closed, but the greatest weight of steam shown by the indicator diagram at any part of the stroke is less than the weight of steam *and water* passing through the cylinder at each stroke. Accordingly, it is argued that a considerable part of that which comes from the boiler as steam goes through the cylinder as water, at least during that part of the stroke when it would, as steam, be of service.

But there have not been wanting some to maintain that the observed, or apparent, effect, as shown by the indicator diagram, is too large for the alleged cause. In January, 1889, Mr. Dickerson of New York, a distinguished patent lawyer, now dead, speaking before the Electric Club of New York, advanced the proposition that the peculiar character of the indicator diagram, which is supposed to show cylinder condensation and subsequent re-evaporation, is really due to leakage of steam past the engine valves, past the exhaust valve in the early part of the stroke, past the admission valve during the latter part of the stroke, the whole effect being to make the *expansion curve*, so called, of the diagram too steep at the beginning, and too nearly horizontal at the end. He made the statement that the steamers in the waters about New York City will make four or five miles an hour with the valve between the boiler and the cylinder closed. I do not know how accurate that statement was, but I have never seen it contradicted. Mr. Dickerson's argument excited my interest, and I cast about for some method of studying the problem of so called cylinder condensation, not, as engineers had done and are still doing, by means of the indicator diagram, but through the cylinder wall by means more familiar to the physicist than to the mechanical engineer. I wished to determine by actual trial how great are the fluctuations of temperature occurring during a complete forward and back stroke of an engine at a given depth of metal from the surface touched by the steam.

For this purpose I naturally had recourse to a thermo-electric device.*

The engine belonging to the Harvard Physical Laboratory, with which my experiments were made, is a Kendall and Roberts of 10-inch cylinder and 15-inch stroke, provided with an ordinary Myer's valve and cut-off. It is jacketed by an air space about 2 cm. wide.

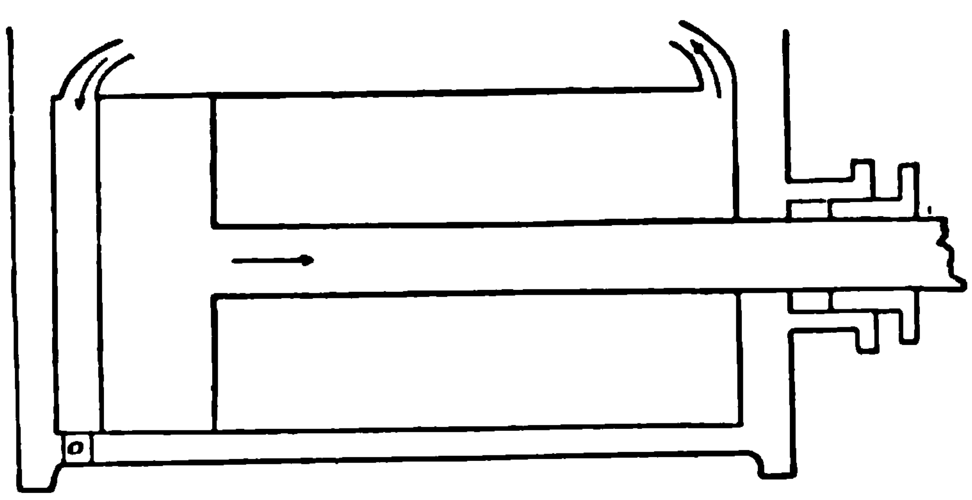


Fig. 1.

Figure 1 shows a horizontal longitudinal section of the cylinder, with the piston at the beginning of its forward stroke. The cylinder wall, about 2 cm. in thickness, is pierced at *o* for making connection with an indicator. Into this hole, which is about 2 cm. wide, I screwed a plug represented accurately enough by Figure 2. On the inner end of this plug was soldered a cover of

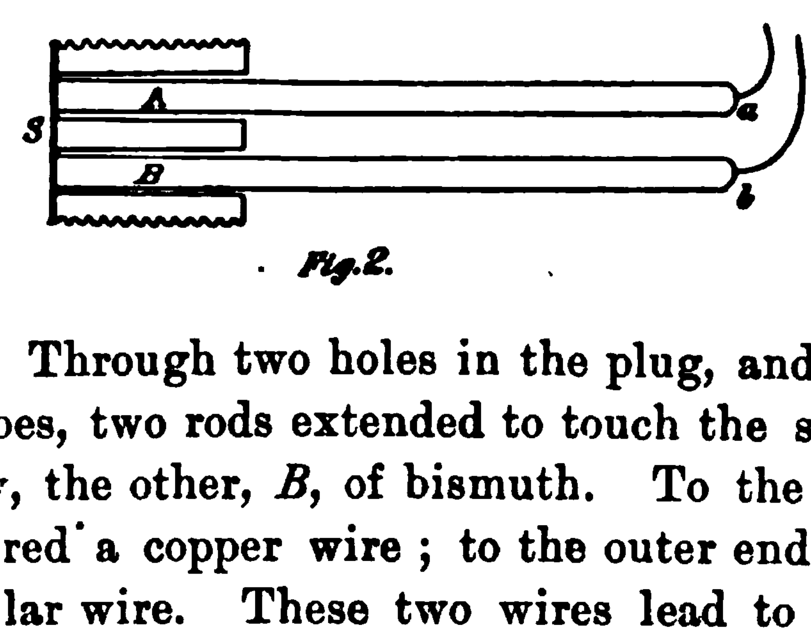


Fig. 2.

thin steel, *S*. Through two holes in the plug, and insulated from it by glass tubes, two rods extended to touch the steel cover, one, *A*, of antimony, the other, *B*, of bismuth. To the outer end of *A*, at *a*, was soldered a copper wire; to the outer end of *B*, at *b*, was soldered a similar wire. These two wires lead to a ballistic galvanometer, but at one point the electric circuit was broken, except

* A letter received from Mr. Bryan Donkin, Jr., of London, the well known engine builder, after the first account of my experiments was published, showed me that he had been before me in making experiments in the same general manner, but with small bulb thermometers in mercury cisterns instead of thermopiles. The *Bulletin de Société de Mulhouse* for 1890 contains some account of his work. My results appear to be not discordant with those which he obtained.

when, at any desired part of the stroke, it was closed for a short time by the revolving crank of the engine. With this apparatus there should be a current, and therefore an effect upon the galvanometer, at closure of the circuit, so long as the two inner ends of the antimony and bismuth bars, which press against the steel, are at a different temperature from the outer ends, which are placed side by side in a pot of melted paraffin or hot oil. But when, on the other hand, there is no effect on the galvanometer at closure, one may, if proper precautions have been taken, conclude that the temperature at that surface of the steel which is touched by the antimony and bismuth, to determine which is the object of the experiment, is the same as that of the heated liquid surrounding the ends *a* and *b*, which a thermometer at once makes known.

This represents one stage of the investigation, but as I gradually became convinced that considerable fluctuations of temperature really occurred at measurable depths of the cylinder wall, I saw that a better considered thermopile than the one at first used was needed. I must discard the steel, the thermal conductivity of which might differ considerably from that of the cast-iron composing the cylinder wall, and must replace the antimony and bismuth by something not very different from cast-iron in thermal conductivity, for it is evident that the temperature existing at any moment at the surface of contact of the iron and the metal outside it may depend greatly upon the conductivity of this second metal. Moreover, this surface of contact should be of considerable breadth, and the contact very perfect; in short, everything should be done to make the surface of contact resemble in all its conditions, as nearly as might be consistently with the object of the experiment, the surface of contact of two strata of iron within the actual cylinder wall. Accordingly, I made the plug and the cover, which now was fastened by four small steel screws to the inner end of the plug (see Figure 3), from the same bar of cast-iron, — not ordinary cast-iron, which would be too brittle for the thin cover, but cast gun-iron of density 7.18, which I found by experiment to have a thermal conductivity not very different from that of ordinary Southern cast-iron of density 7.06. In place of the antimony and bismuth bars I now used a single cylinder of cast nickel of density 8.08, the thermal conductivity of which I have found by experiment to be very nearly the same as that of the cast gun-iron at 115° or 120° Centigrade. The specific heat of nickel is about the same as that of iron.

Notwithstanding the great similarity of cast-iron and cast nickel in many respects, they make a powerful thermo-electric couple, so that nickel appeared to be of all substances the one best fitted for my purpose. The hole bored in the iron to receive the nickel cylinder was about 0.65 cm. in diameter. The cylinder itself was about 0.025 cm. less in diameter, so that when wrapped with a single layer of ordinary printing paper it would fit rather snugly in the hole. The cast-iron plug with its cap in place was about 2.2 cm. long, and the nickel cylinder projected very slightly beyond the outer end of the plug.

The inner end of the iron plug, the inner end of the nickel core, and that surface of the iron cap which was to press against them, were all worked with great care to a plane polished surface. The cap and the nickel core were then soldered together in the following manner. That part of the cap surface which was to meet the nickel was thinly tinned with ordinary solder and then the cap was screwed firmly into place upon the plug. That end of the nickel which was to meet the iron was also tinned, and then this core, wrapped, save at the ends, by a single layer of paper, was thrust into the hole in the plug. The plug with its contents was then heated very hot, and while hot was placed in a vise between blocks of wood, which by the action of the vise pressed the nickel core and the iron cap so close together that the layer of solder left between them was, according to my measurements, less than 0.002 cm. thick. Then, after cooling, the screws holding the cap in place were drawn out, and cap and core were carefully removed from the plug. The excess of solder which had been pressed from between them, and which had gathered about the base of the core, was then carefully turned off in a lathe with a brass tool. The core was then wrapped with fresh paper and put back in place, the cap being carefully screwed on. Red lead was used around the screws holding the cap, but I depended mainly upon the perfection of the contact between cap and plug to prevent leakage at this joint.*

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* In some of the experiments this joint was not perfectly tight, for water was sometimes seen to come out past the core, N, before the plug became hot. Generally upon such occasions the leaking appeared to cease when the plug became hot. The fact probably is that the joint continued to leak slightly, but leaked dry steam, the temperature at the outer end of the plug being about 110° C., and at the inner end considerably higher. Both experiment and reason indicate that the effect of such leakage upon the temperatures observed was slight.

Three plugs were thus completed, the caps being respectively 0.051 cm., 0.101 cm., and 0.203 cm. thick. All the iron parts were from one bar, and all the nickel parts were from one bar.

From the nickel core of each plug when in use extended a slender bar of nickel about 15 cm. long, made from the same piece as the core, and from the outer end of the iron plug extended a similar bar of iron made from the same piece as the plug. The bars were not rigidly fastened to the nickel core and the iron plug, but were held by friction in holes bored to receive their ends. The outer ends, *i* and *n*, Figure 3, extended through a plug of hard rubber, *P*, screwed into the thickened wall, *WW*, of a vessel containing melted paraffin, and copper wires soldered to these ends led back through the hard-rubber plug toward the galvanometer, which was about 60 m. distant. To facilitate adjustments the central hole of the

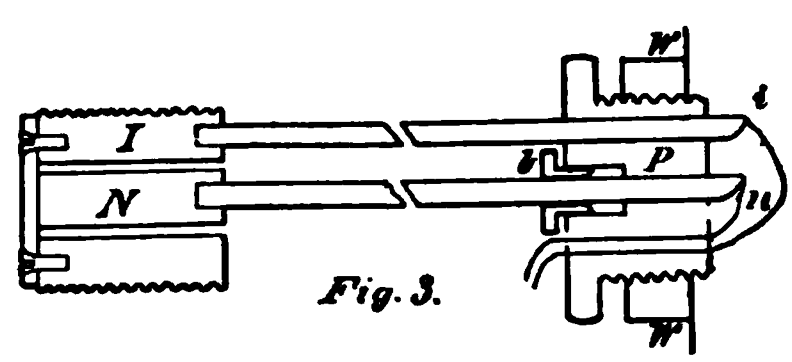


Fig. 3.

hard-rubber plug was made somewhat too large for the nickel connecting bar reaching through it, and a stuffing-box, *b*, was depended on to prevent leakage past this bar. The bulb of a thermometer hung near the junctions *i* and *n* in the melted paraffin, which was heated by a lamp placed below and was stirred by a mechanism driven by the engine.

The key by means of which the electric circuit could be closed for a short part of each stroke required some thought in its evolution, and will be described with detail, although no doubt it might be improved.

At one stage in my experiments I tried making contact by means of a fork-shaped spring of brass, which revolved with the engine crank, and at one part of the stroke bestrode a gap in the circuit, rubbing with each prong upon brass. A certain amount of thermoelectric force was to be expected at each of the two rubbing points of contact, but I had hoped that the two forces would counteract each other sufficiently for my purpose. In this I was disappointed, and I afterwards endeavored to avoid rubbing at the point of closure of the circuit. The key finally used was essentially like

that shown in Figure 4, in which B is a block of hard wood about 14 cm. long on the upper curved edge, 6 cm. thick, and 5 cm. wide. The brass spring S fastened to the top of the block is connected by means of the wire l with the galvanometer. The brass spring S' also fastened to the top of the block, is connected by means of the wire l' with one of the junctions i or n in the pot of melted paraffin. The two springs do not at present touch each other, but will do so at P, as soon as S' is lifted by the lever LL, which is pivoted at a, and will be struck at E by the cam K on the engine crank. The lever LL works in a narrow slot sawed in the block B. To prevent short circuiting through the body of the engine this lever

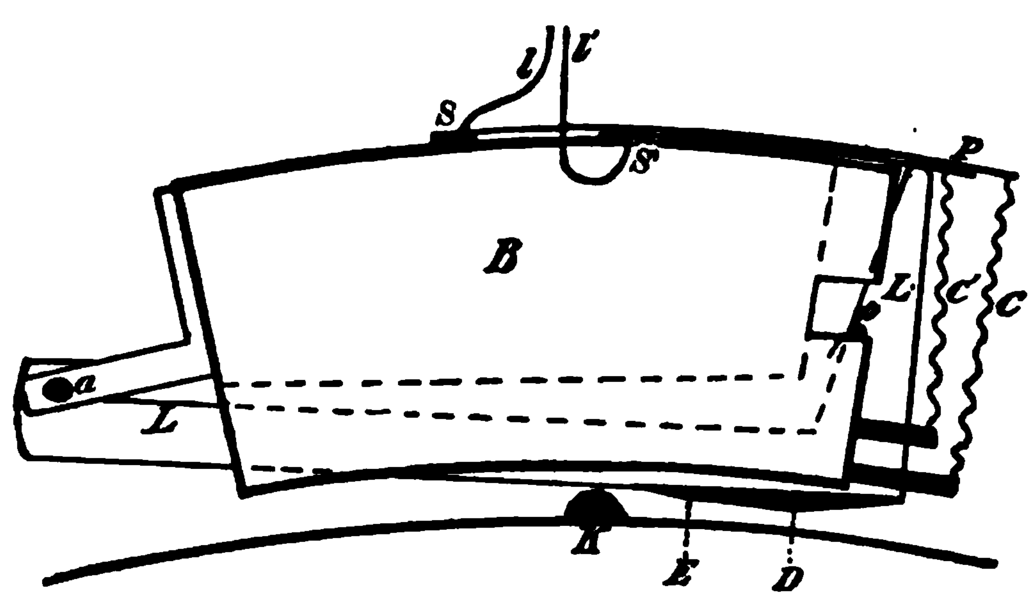


Fig. 4.

is tipped with hard rubber where it touches the spring S'. The electromotive force which one has to deal with in this experiment is so small that a mere touch of S' against S is not sufficient. Contact must be maintained for a short time, and for this purpose the lever LL is so shaped that the cam K rubs against it all the way from E to D, about one sixtieth of a revolution, one sixtieth of a second in my experiments. To prevent illegitimate contacts or illegitimate breaks between S and S', each of these strips is controlled by two stiff spiral springs, which are indicated by C for S, and by C' for S'. The motion of S is, moreover, limited by stops, not shown in the figure, placed above and below at the end. The lever LL is made of thin sheet brass in order that its momentum may not be troublesome, but the part ED, along which contact with K endures, is reinforced by a narrow strip of iron soldered on. A pin, p, keeps LL in contact with S' when both are at rest, and prevents the lever from dropping so far as to be struck too hard by K.

To prevent thermo-electric troubles I used continuous wires from this key to the distant room where the astatic galvanometer was placed. This was an instrument of tolerable, but not extraordinary, sensitiveness. Its resistance was probably about five ohms, and the time of a single vibration about six seconds. I have spoken as if the electric circuit were closed at every stroke of the engine by the key just described. In fact, the circuit was closed only when this key and another under the hand of the observer at the galvanometer were in operation simultaneously. The method of procedure did not require measurement of the galvanometer deflections. It merely required the observation of that temperature in the paraffin pot which should make the galvanometer deflections zero. The period of vibration of the needle was so much greater

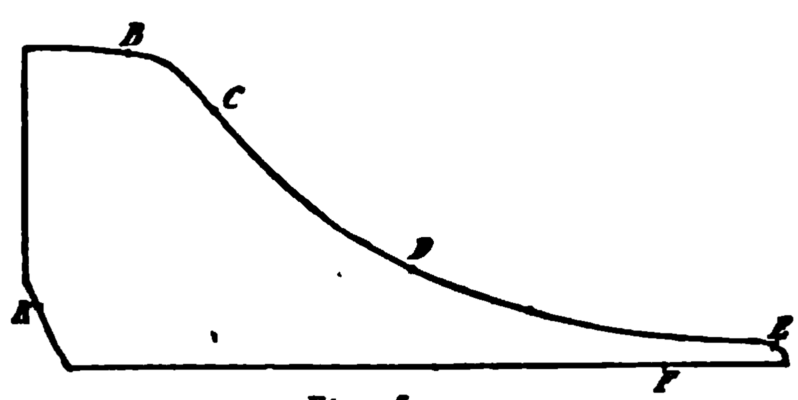


Fig. 5.

than the time of a stroke of the engine, that, by holding his key down for several strokes in succession, the observer at the galvanometer could magnify any effect produced upon the instrument, and therefore determine more sharply when the desired condition of no effect was reached.

The method of work was somewhat as follows. Everything being in readiness, the observer at the galvanometer would satisfy himself by trial that the closed circuit, *with the iron-nickel thermopile omitted*, had no perceptible effect upon the galvanometer. He would then signal for the thermopile to be brought into action, and, watching the galvanometer, would determine whether the paraffin was too hot or too cold for equilibrium, and signal the other experimenters accordingly. If it was too cold, finely divided paraffin was thrown into the pot, while some of the overheated liquid was drawn off through a cock at the bottom. The following set of observations was made on April 17, 1891, with the 2 mm. thermopile, contact occurring near the point of cut-off (Figure 5, *C*).

Time.		Temp. of Paraffin.
3:16	Thermopile out. No certain effect.	
	Thermopile in.	°
3:21¼	Effect uncertain.	130.0
3:22½	Scale to right.	130.4 ?
3:23¼	" "	133.6
3:24½	" "	137.7
3:26¼	" "	133.2
3:27	" "	131.4
3:27½	Effect uncertain.	129.5
3:28¼	" "	126.5
3:28¾	Scale to left.	125.0
3:29¼	" "	123.6
3:30½	" "	124.4
3:31¾	" "	126.7
3:33¼	Scale to right.	130.6
3:34¾	" "	131.0
3:35¼	" "	129.5
3:36	Effect uncertain.	127.5
3:36¾	Scale to left.	125.5

This was the first set of observations made after a rather important change in the apparatus, and shows lack of skill. The next series, made the same day, is somewhat better. The same thermopile was used, but contact was during the latter part of compression, just before admission of new steam, near the point K in Figure 5.

Time		Temp. of Paraffin.
3:50	Thermopile out. No certain effect.	°
3:52	Effect uncertain.	124.1
3:53½	" "	125.0
3:54	Scale to right.	124.9
3:54½	" "	125.0
3:55½	" "	127.0
3:56¼	" "	126.2
3:57¼	" "	125.2
3:57¾	" "	124.6
3:58½	" "	124.0
3:59½	Scale to right, slightly.	123.5
4:0⅙	?	?
4:1	Scale to left.	122.8
4:1¾	" "	122.3
4:2½	" "	122.0
4:3¼	" "	121.8
4:4½	Effect uncertain.	122.5
4:6¼	Scale to right.	124.3

While such observations as those just recorded were being made, one observer was usually engaged in taking indicator diagrams from

Date.	Part of Stroke.	Point in Fig. 5.	Temperature at Depth of		
			0.051 cm.	0.101 cm.	0.203 cm.
	Inches.				°C
April 17	3.31– 3.94	C	. . .	. . .	129.5
" 17	14.84–14.97	E	. . .	. . .	129.
" 17	0.22– 0.06	K	. . .	. . .	124.5
" 24	14.84–14.97	E	°C. 123.0		
" 24*	0.22– 0.06	K	122 ?		
" 27	3.31– 3.94	C	183.0		
" 27	12.53–12.00	F	119.0		
" 27	0.22– 0.06	K	119.5		
May 6†	12.53–12.00	F	124.0		
" 8	12.53–12.00	F	124.0		
" 8	1.78– 2.38	B	186.0		
" 8‡	7.25– 7.94	D	122.5		
" 11	8.81– 3.94	C	. . .	°C. 135.5	
" 11	7.25– 7.94	D	. . .	184.0	
" 11§	14.81–14.94	E	. . .	129 ?	
" 15	14.31–14.94	E	. . .	128.5	
" 18	8.81– 3.94	C	. . .	. . .	°C 128.0
" 18‖	14.81–14.94	E	. . .	. . .	126.5 ?
" 18‖	0.22– 0.06	K	. . .	. . .	123.5 ?
" 18	0.22– 0.06	K	. . .	. . .	123.0

* In this set of observations a substitute took the place of the usual observer at the galvanometer.

† The thermopile leaked badly past the nickel core during this set of observations. It was put in order before the observations of May 8, when it appeared to be perfectly tight.

‡ The temperature of equilibrium appeared to fall in this set of observations from near 123°.5 to near 121°.5.

§ From a short set of observations in which the temperature was not well controlled.

‖ Nickel connecting bar found apparently loose at connection with core at end of series of observations.

the engine, and noting at frequent intervals the number of strokes per minute. The general type of the diagrams is shown in Figure 5. The maximum pressure during admission was generally near 34 lb. above atmospheric pressure, and cut-off occurred near one quarter stroke. Wishing to have the diagrams affected as little as possible by the action of the governor, I depended largely upon the load, which was a dynamo with closed circuit, to regulate the speed of the engine to sixty strokes per minute. The steam pressure, however, was by no means constant, and the speed sometimes rose or fell two or three strokes from the desired figure. This inconstancy, and the discrepancy of thermometers, one or two of which were broken during the experiments, may help to account for some lack of consistency in the results obtained, which are presented in tabular form on page 46, estimated stem corrections having been applied to the thermometer readings.

I have omitted from this table all results of observations made previous to April 17, 1891, for the reason that in these earlier observations the time during which contact lasted was about three times as long as in later ones. Nevertheless, the results obtained with the long time of contact are in general agreement with those obtained later, and as in the table there is no record for the depth 0.101 cm. at that part of the stroke marked by *K* on the indicator diagram, I shall fill this gap, as well as I can, from a comparison of the earlier observations with the later, which comparison indicates the temperature 123°. I shall undertake to show by means of a diagram, Figure 6, the temperature condition of the inner part of the cylinder wall as indicated by my observations at three points of the stroke, *C*, *E*, and *K*. Distances into the cylinder wall from its inner surface are laid off along the base line of the diagram from right to left. Temperatures in excess of 110°.5, the temperature of the outer surface of the cylinder wall, are measured upward from this base line. Line *K* indicates the condition of things just before admission of new steam; line *C*, the condition at or near the time of cut-off; line *E*, the condition near the end of the forward stroke. The broken parts of curves are extensions beyond the region of actual observation. It is easy to see that an error of one or two degrees in the observation of temperature at the depth 0.051 cm. would make a great difference in the position of the broken part of the curve to which this observation belongs, and it is evident that the broken part of curve *C* cannot be correct, for it indicates at the inner surface of the cylinder wall a temperature some degrees

lower than that of the steam in the cylinder at this instant, as calculated from the indicator diagram. We cannot suppose this possible, for during the admission of steam this inner surface must have become very nearly as hot as the steam itself, else the interior strata of the iron could not have become heated to the extent observed, and the inner surface could not, after being thus heated, cool faster than the steam in front of it and the iron behind it. The same objection cannot be made to curves *E* and *K*, yet the broken parts of these curves are open to much doubt, and it is not certain that they should cross each other. A much more accurate determination of temperatures than I have made is needed to draw

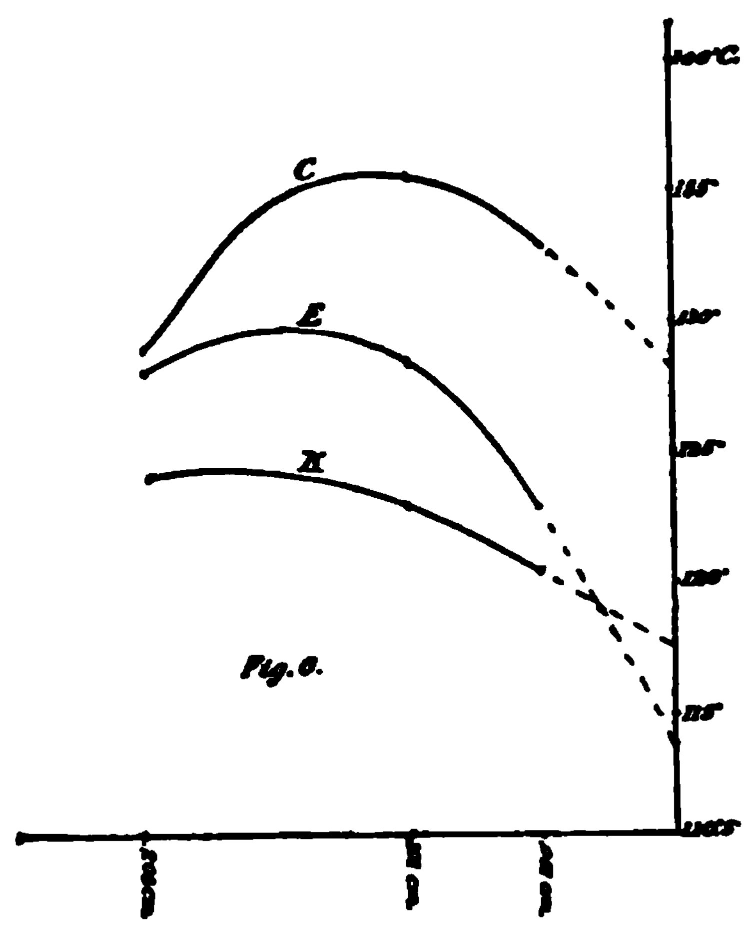


Fig. 6.

any one of the three curves with confidence. Moreover, observations at a depth of 3 mm. are desirable, though under the conditions of my experiments the fluctuations of temperature at that depth are probably not more than one or two degrees.

Disregarding inaccuracies of the diagram, I shall now undertake a rough estimate of the amount of heat contained by the cylinder wall at the instant of complete cut-off, as indicated by the curve *C*, in excess of the amount which it contained just before admission, as indicated by curve *K*. The planimeter will show that the average temperature along that part of curve *C* shown in the diagram exceeds the average temperature along that part of *K* there shown by nearly 12° Centigrade. This is equivalent to a uniform elevation of about 2°.4 extended to a depth of 1 cm. Taking the

specific gravity of iron to be 7.2 and the specific heat to be 0.113, we find that through each square centimeter of the inner surface of the cylinder wall exposed to the steam during the *whole* time of admission, there have entered $2.4 \times 7.2 \times 0.113$ ($= 1.95$) c. g. s. units of heat. I estimate the surface exposed to steam in cylinder and port when admission *begins*, to be 1700 sq. cm. If we estimate the piston face and port surfaces to be only two thirds as effective for condensation as an equal surface of cylinder head, we may reduce this area to about 1400 sq. cm. The movement of the piston *during* admission exposes about 700 sq. cm. more of the curved cylinder surface. If we count this as being equivalent to 350 sq. cm. exposed during the whole of admission, we have $1400 + 350$ ($= 1750$) sq. cm. as the *effective* area of the surface upon which condensation occurs during admission. The whole amount of heat absorbed through this surface in this time is, then, 1750×1.94 (= approximately 3400) c. g. s. units. This would correspond to the condensation, at 49 lbs. absolute pressure, of $3400 \div 510$ (= approximately 6.7) grams of steam. The weight of *steam* in the cylinder at the end of the forward stroke was, according to the indicator, about 13.5 grams. The weight of steam in the cylinder at cut-off was considerably less than this, probably about 10 grams. According to this calculation, then, the amount of steam *condensed* during admission was about two thirds as much as the amount not condensed, and about one half of the condensed portion was re-evaporated during expansion. The amount re-evaporated during the exhaust was probably much less, for the curves of Figure 6 indicate that much less heat flowed back to the inner surface during exhaust than during expansion, and we know that a very considerable amount of heat passes *through* the wall.

A very rough estimate of water consumption, made May 8th, indicated that about 23.5 grams of water and steam passed through each end of the cylinder at each stroke. The calculations, or conjectures, just made account for rather less than three fourths of this, but the discussion goes to show that the ebb and flow of heat indicated by these thermo-electric experiments is of the right order of magnitude to account for a large part of the cylinder condensation, and to encourage the hope that a careful and extended set of such experiments would yield results of great certainty and value. I am not prepared to undertake such a labor at present, but the thermopiles which I have used in this preliminary investigation

have now been placed in the hands of two students of mechanical engineering in a well known Professional School, and I look for interesting results from their work.

For indispensable assistance in the work which this article describes I am indebted to Messrs. Barron, Curtis, Hale, Kendrick, and Page, members of a class at Harvard College engaged in a study of the steam-engine.

IV.

NOTE ON AN APPROXIMATE TRIGONOMETRIC EXPRESSION FOR THE FLUCTUATIONS OF STEAM TEMPERATURE IN AN ENGINE CYLINDER.

By Edwin H. Hall.

Presented January 11, 1898.

During one of the long interruptions of an experimental investigation of cylinder condensation in steam-engines,* I was moved to attack the problem mathematically, making use of the well known methods of treating heat conduction, which are set forth to advantage in Riemann's *Partielle Differentialgleichungen*. I carried the process far enough to see that the waves of heat produced at the inner surface of the cylinder wall, by the fluctuations of steam temperature during each stroke of the piston, would penetrate to a considerable depth; but the labor of a complete investigation of the problem by this method seemed likely to be much greater than that required by the experimental method, while the results would necessarily be open to considerable doubt, owing to the assumption that one must make in estimating the temperature of the inner surface of the cylinder wall at any point of the stroke. I therefore returned to my experiments, convinced that experiment alone could give the results for which I was striving. Nevertheless, it may be of interest to those concerned with problems of heat conduction, theoretical or practical, to see the result of the first mathematical steps, the derivation of an approximate trigonometric expression for the periodic changes of temperature suffered by the steam during each complete stroke of the piston.

The indicator diagram, Figure 1, gave the pressure, and so the temperature, of the steam at every point of the stroke. Assuming the engine piston to have simple harmonic motion, that is, neglecting the effect of the *vertical* movement of the crank pin, I plotted a

* See *ante*, page 37.

curve, the heavy line of Figure 2, ordinates representing temperature in excess of 100° C., and abscissas representing phases of the

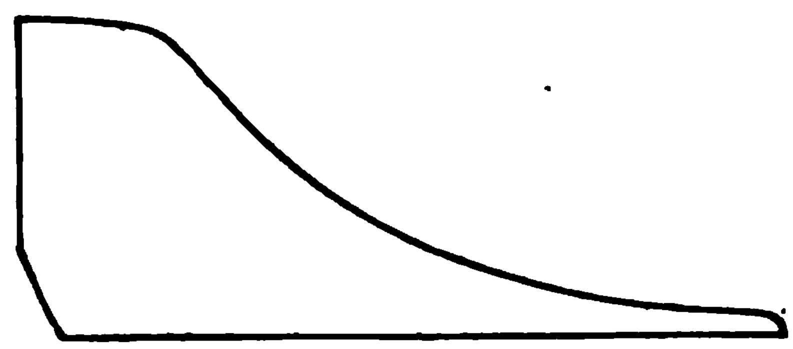


Fig. 1.

stroke in terms of the angular distance of the crank pin from its zero position, the position occupied at the end of the out stroke. The left end of the base line indicates $-\pi$, or $-180°$, the beginning of forward stroke; the middle of the line represents 0°; the right end represents $+\pi$, or $+180°$, the end of back stroke. Thus the

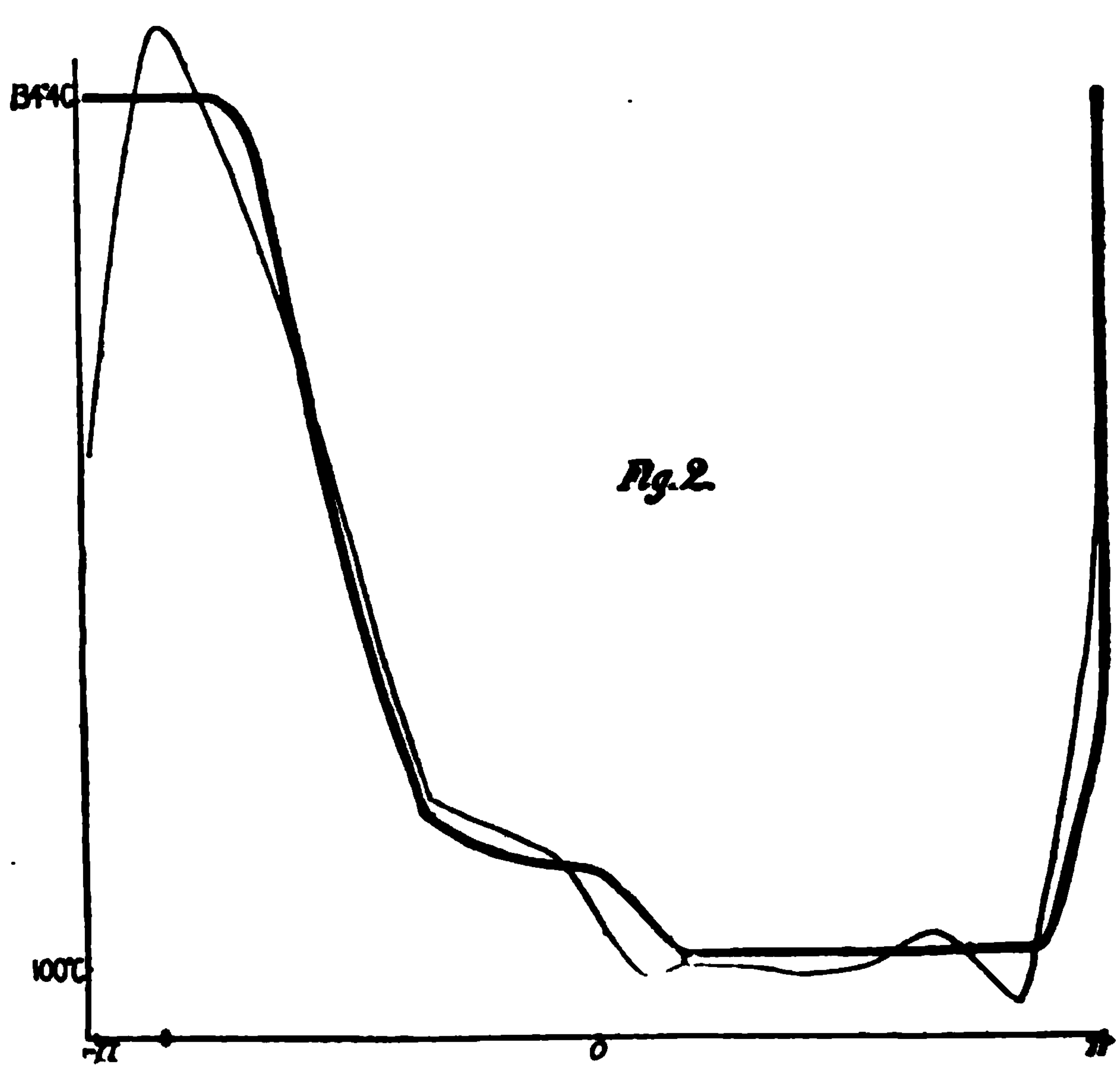


Fig. 2.

cycle of a complete forward and back stroke is compassed, and the length of the base line is called 2π.

My task now was to find a mathematical expression for any ordinate, y, of the given curve in terms of the corresponding abscissa, x; that is, to write $y = \phi(x)$, and find the form of the function ϕ.

It is well known that for any continuous curve, however irregular, extending from $x = -\pi$ to $x = \pi$, the relation of any y to the corresponding x may be written as follows: —

$$y = \phi(x) = \tfrac{1}{2} b_0 + b_1 \cos x + b_2 \cos 2x + \ldots + b_m \cos m x + \ldots$$
$$+ a_1 \sin x + a_2 \sin 2x + \ldots + a_m \sin m x + \ldots$$

The length of this series of terms may be, and usually is, infinite, but frequently a comparatively small number of terms will express the required relation with sufficient accuracy, when the values of the coefficients b_0, b_1, a_1, etc. are known. I used eleven terms, six containing b coefficients and five containing a coefficients, and the labor of determining the coefficients was considerable. The general expression for any b coefficient is

$$b_m = \frac{1}{\pi} \int_{-\pi}^{\pi} \phi(a) \cos m\, a\, d\, a,$$

and for any a coefficient

$$a_m = \frac{1}{\pi} \int_{-\pi}^{\pi} \phi(a) \sin m\, a\, d\, a,$$

in which expressions a is any variable beginning with the value $-\pi$, and increasing regularly to $+\pi$, and $\phi(a)$ bears to a the same relation that $\phi(x)$ bears to x. The process of obtaining the value of any coefficient is mainly graphical. To illustrate, let us take the case of b_2. The value of $\cos 2a$ was found for fifteen values of a, beginning with $a = -\pi$, and ending with $a = +\pi$. The corresponding values of $\phi(a)$ were obtained from the heavy curve already described in Figure 2 by measurement of the ordinates corresponding to the chosen values of a. Then the product $\phi(a) \cos 2a$ was taken for each of the chosen values of a, and, a new base line extending from $-\pi$ to $+\pi$ having been laid off, these products gave the values of the ordinates at the chosen fifteen points along this base line. Through the tops of the ordinates a curve was drawn, and the area between this curve and the base line was measured by means of a planimeter. This area gave the value of the definite integral

$$\int_{-\pi}^{\pi} \phi(a) \cos 2\, a\, d\, a.$$

The values thus found for the various coefficients were as follows: —

	For Fahr. Scale.	For Cent. Scale.	For Fahr. Scale.	For Cent. Scale.
b_0	35	19.3+		
b_1	−16.9	−9.4	$a_1 =$ −20.7	−11.5
b_2	1.9	1.1−	$a_2 =$ 14.1	7.8+
b_3	1.7	1.0−	$a_3 =$ −7.6	−4.2+
b_4	0.4	0.2+	$a_4 =$ +3.1	1.7+
b_5	−1.4	−0.8−	$a_5 =$ −3.2	−1.8−

The faint line of Figure 2 shows the curve really represented by the formula $y = \phi(x)$. As every new coefficient requires, in general, more work for its determination than those preceding, I attempted no closer approximation to the actual curve of the steam temperatures than is shown in this diagram.

V.

STUDIES ON THE TRANSFORMATIONS OF MOTHS OF THE FAMILY SATURNIIDÆ.

BY A. S. PACKARD, M. D.

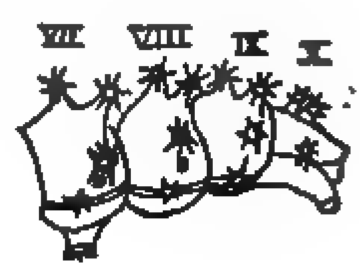
Presented February 8, 1893.

THE larval characters of the members of this interesting group, especially those features which are congenital, tend to show that the family has originated from some spiny group, and most probably, when we take into account the transformations of *Aglia tau*, from the Ceratocampidæ, although none of the latter spin a cocoon. During the evolution of the group they underwent a change in shape, from a rather long and slender form to a thick heavy body, with a thin integument, the result perhaps of an unusually stationary mode of life. The imagines also underwent a process of degeneration, as seen in the atrophy, total or partial, of the maxillæ, and in the loss of veins in their very large but weak wings ; though the loss of strength of flight is somewhat compensated for by the remarkable development of the olfactory organs, or antennæ.

This family also appears to be a closed type ; viz. none of the higher or more specialized Bombyces appear to have descended from it (unless possibly the Cochliopodidæ), the type representing a side branch of the Bombycine tree which late in geological history grew apart, and reached a marked degree of modification, resulting in the possession of adaptive characters which were not transmitted to later forms. It seems probable that the type was a Miocene Tertiary one, which has lingered on in Eastern America (North and South), and in Eastern Asia, as well as in Africa, while it has become nearly extinct on the Pacific shores of North and South America, and in Europe.

Saturnia (in its restricted sense) the most generalized Genus of its Family. — In the European *Saturnia carpini* and its allies, and our Pacific coast species, *Saturnia mendocino* and *S. galbina*, the larva of the former species having been described by the late Henry Edwards (Proc. Cal. Acad. Sci., Dec. 17, 1877), we have perhaps the most generalized and primitive members of the family. In the larva of

Saturnia carpini, for a specimen of which I am indebted to M. P. Chrétien of Paris, the setiferous tubercles are of the same size and shape on the abdominal as on the thoracic segments, there being no differentiation in shape and size or color, such as occurs in all the other genera, except that the second and third thoracic dorsal tubercles bear one or two bristles much longer than those on abdominal segments 1 to 7, and about as long as those on the 8th abdominal segment. There are *six* tubercles on this (8th) segment, being the same number as on the seven segments in front; on segment 9 there are four tubercles, and two on the 10th segment, i. e. the suranal plate. The same number of tubercles on the 8th abdominal segment also occurs in *Saturnia mendocino** of California. Likewise the same number is present in the European *S. pyri*, judging by the figure and description in Duponchel et Guenée's Iconographie (II., Pl. I.), and the statement, "On ne compte que quatre tubercules sur le premier anneau, de même que sur le dernier, tandis que les intermédiaires en ont chacun six." It is also figured in Hübner's Schmetterlinge.



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B

A

Figure 1, A, represents a dorsal view of the end of the body of the larva of *Saturnia carpini*; B, the end of the body of *S. pyri*, copied from Duponchel.

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* We copy Mr. Edwards's description of this larva, to show that the same characteristic of *six* tubercles on *all* the abdominal segments 1 to 8 occurs in the Pacific coast species of the genus: — "*Full grown.* Head small, rough, purplish brown, somewhat withdrawn into the second segment. Ground color of the body, pale yellowish green. On the second and anal segments are four tubercles each, bright orange-red, with black hairs springing from them, and on each of the other segments are six similar tubercles, those of the anterior four being the largest. Head and body thickly clothed with whitish hair. Laterally there is a pale yellowish fold above the spiracles, which are orange with a darker ring. Feet and under side purplish brown. Length 2.25 inches. Food plant, *Ardistophylus tomentosa*."

Indeed, the extremely generalized form of the larvæ of this genus is clearly shown by the fact that in *P. cecropia*, and all the other more specialized and hence later genera, there are only five tubercles on the 8th abdominal segment, those corresponding to the two middle ones of Saturnia having, probably during embryonic growth, coalesced. The embryos of these moths should therefore be examined shortly before hatching to ascertain whether this be not the fact. Meanwhile it is not unreasonable to suppose that all the more specialized genera must have been derived from a Saturnia-like ancestral form, i. e. a larva of cylindrical shape, with all the tubercles, whether thoracic or abdominal, of the same size, shape, and color on all the segments; those on the 8th abdominal segment being of the same number (six) as on the segments in front.

The single median tubercle on the 8th abdominal segment of the more specialized Saturnian larvæ represents the "caudal horn" of Sphinges, *Bombyx mori*, and the Notodontian genus Pheosia, and is evidently the result of fusion before the end of embryonic life of what were originally two separate tubercles, like the two separate ones of Saturnia. We are thus able to confirm the suggestion of W. Müller, who first identified the "caudal horn" with the two dorsal tubercles on the 8th abdominal segment of the Saturniidæ.*

Thus as regards the tubercles the species of Saturnia are on the

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* W. Müller, Südamerikanische Nymphalidenraupen, 1886, pp. 249, 250. Müller remarks: —

"So erscheint es berechtigt, für das Schwanzhorn der *Sphingidæ* die gleiche Genese anzunehmen wie für den unpaaren Dorn der *Saturniadæ* auf 11. Beide sind entstanden aus den Stützgebilden der beiden Borsten 1 auf Segment 11. . . . Weiter finden sich bei einer Raupe, augenscheinlich den Saturniden angehörig, in einem früheren Stadium *Sds* auf 2, 3, *Ds* 11; mit der nächsten Häutung verschwinden die sämmtlichen Dornen. Bei *Brohmea lederern* finden sich im 3. (?) Stadium *Ds* 11, *Sds* 2–10, 12, *Sst* 4–11, von welchen Dornen die *Ds* 11, *Sds* 2, 3 stark entwickelt, die anderen klein, unscheinbar sind. Im 4. (?) Stadium sind die *Ds* 11, *Sds* 2, 3 wohl entwickelt, die anderen Dornen sind kaum nachweisbar. Im letzten Stadium bleibt nur eine Warze an Stelle des *Ds* 11; es erhält sich also der Rest von *Ds* 11, am längsten.

"Mir scheinen alle diese Gründe zur Annahme zu drängen, dass das Schwanghorn der Sphingiden der Rest einer reicher entwickelten Bedornung ist, einer Bedornung, die vielleicht mit der heutigen der Saturniden auf gleichen Ursprung zurückzuführen ist, so dass das Schwanzhorn der Sphingiden und der *Ds*dorn der Saturniden im vollen Sinn homolog sind."

See also E. B. Poulton in Trans. Ent. Soc. London, 1885, p. 302, and in later papers; also A. S. Packard, Proc. Bost. Soc. Nat. Hist., XXV., 1890, pp. 99, 103, foot-notes 1, 2, 3. Also compare our Figures 3–6, 8–10 *d'*, and the references to them in the text. Also Grote's N. A. Lepidoptera, Bremen, 1886, pp. 16, 54.

same plane with the embryo, just before exclusion, of the more highly specialized forms of the group Attacinæ. The great size of the Attacinæ, particularly *Attacus atlas*, appears to be a sign of recent specialization, and the small size of Saturnia, aside from its other features, suggests that it is a generalized form, not departing greatly from the normal size of the members of the superfamily Bombyces.

And here an interesting problem in zoögeography occurs. Are the species of Saturnia (in the restricted sense) — three in Europe, and two in the Southwest and Pacific Coast of North America, occurring where the Attacinæ do not exist at all, or only rarely — the relics of a Saturnian fauna from which the group Attacinæ has been eliminated by geological extinction, as the sequoia, cypress, magnolia, and other Tertiary plants have been rendered extinct in Europe, or may the view be taken that the Attacinæ have never had a foothold in Western Eurasia and North America?

Should we use the characters drawn from the number and arrangement of the tubercles of the larva in classifying the Saturniidæ, we might divide the family into two groups, as follows: —

A. Six tubercles on the 8th abdominal segment; the tubercles in general over the body all of the same size. Generalized forms.

Subfamily 1. *Saturniinæ.*

B. Five tubercles on the 8th abdominal segment, the median one double; the tubercles in general more or less differentiated or specialized in size and color. Specialized forms.

Subfamily 2. *Attacinæ.*

An interesting series of parallelisms may be observed in comparing the early and later stages of the larvæ of this family. For example while the late embryos of the Attacinæ are perhaps paralleled by the fully grown larva of Saturnia, the fully grown larva of the most or one of the most generalized Attacinæ, Platysamia, is on the same plane of specialization as the larva of Callosamia in its third stage.

The Life History of Platysamia cecropia (Linn.).

From some eggs received from Mr. H. Meeske, of Brooklyn, N. Y., the larvæ hatched out at Providence during the night of June 14.

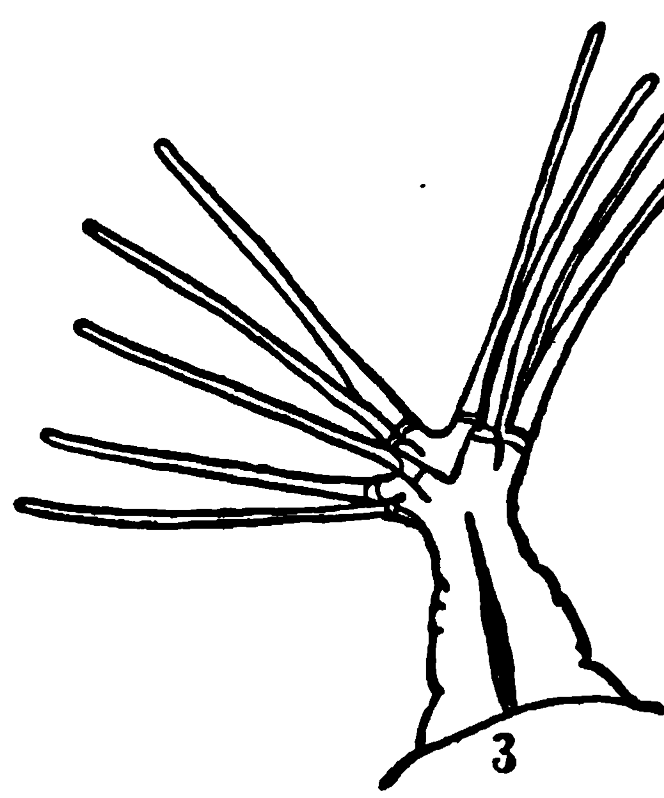
Egg. — It is large, flattened, oval-cylindrical. Length 2.5, breadth 2 mm. The shell is dull chalky white, is seen under a triplet to be pitted, but under a half-inch objective the pits are seen to be in close irregular wavy parallel rows, the pits themselves showing a tendency to be grouped into twos or threes.

Larva, Stage I. — Length when first hatched (June 15), 6 to 7 mm. On emerging from the egg the larva is mostly black, the head, body, and hairs are jet-black, but the tubercles are pale yellowish green, the hairs or bristles they bear being black; the abdominal legs also are pale, the thoracic ones black; shortly after emerging the larva turns entirely black. One larva was observed drawing itself slowly out of the hole it had gnawed in the egg, having eaten its way through the egg-shell at 11.30 A. M., June 15. It was mostly black, but the pale yellowish green tubercles were flattened down close to the body, and the hairs or setæ in each verticil or pencil were united in one pencil-like mass and bent to one side on the body. The abdominal legs were pale livid, the thoracic ones black. In ten minutes more the tubercles had become erect, higher and longer (probably swelled out by the presence of the blood), and by this time the hairs had assumed their radiate arrangement.

In one or two minutes more, viz. from 11 to 12 minutes after extricating itself from the egg, the tubercles had all become of full length, and erect, and the black setæ, or hairs, had now spread out in a verticillate way, as normal. In an hour more the larva had turned perceptibly darker, and in three quarters of an hour more it had turned entirely black. The spiracles, however, are yellowish green, and thus are rather conspicuous. The body is stout and thick, the head is as wide as the body. On the prothoracic segment are four dorsal tubercles, two on each side of the median line. Along the body are six rows of tubercles, each usually bearing about five radiating setæ; those of the two dorsal series are larger than the subdorsal ones. The tubercles are rather short and stout, fleshy; and are one half to two thirds as long as the bristles. The latter are stout, taper to the end, which under a half-inch objective is seen to be blunt, slightly bulbous, and clear, so that these setæ are evidently glandular in function; they are slightly rough with rudimentary spinules. On the 8th abdominal segment, instead of two tubercles, one on each side of the median line, as on abdominal segments 1 to 7, there is a single median tubercle, about twice as large round as those on each side, though no higher, and it is evidently the result of the concrescence in the embryo stage of two tubercles, such as are to be seen on the segments in front. It is transversely broad at base, and also bears eight or ten setæ, or nearly twice as many as the homologous tubercles on the other segments. The thoracic feet bear at their tips three lancet-shaped flattened acute tenant hairs; while the abdominal legs bear about 16 crotchets.

Figure 2 (Plate I.) represents the last three abdominal segments; VIII. bearing the median double tubercle *d'*, and IX. the 9th pair (the right subdorsal tubercle on the 9th segment not being drawn); X. the suranal plate with its armature, the two lateral tubercles, bearing each six setæ; the tubercles in front usually bear five setæ.

Figure 3. The double median dorsal tubercle of the 8th abdominal segment, showing a light median furrow, the probable line of union of what in the embryo were originally separate tubercles; it bears ten setæ, arranged in two lateral groups of five each.



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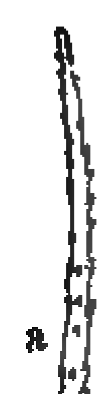
Stage II. — (Described one or two days after moulting.) Length 14 mm. The head now is quite small, scarcely one half wider than the body; it is entirely black.

The body is dull dusky livid greenish; the tubercles are somewhat yellowish at base on the conical portion, but *the slender chitinous portion is shining black*, and the radiating bristles are all black; one or two of them are longer than the column or chitinous portion of the tubercle. *The thoracic tubercles are slightly longer than those on the abdominal segments*, and the single median one on the 8th abdominal segment is slightly larger than those on the 7th and 9th segments, and is now about twice as thick as those on the side, and bears eight bristles, the lateral ones on the same segment bearing five. The prothoracic segment is a little darker than the others; it bears a chitinous black plate about four times as broad as long, bearing on the front edge four setiferous tubercles of equal size, one at each end, and with two yellow spots. The tubercles in general are now long and slender, with a conical base, the stalk contracted and rather slender in the



Armature of Attacine Caterpillars.

middle, the head enlarged and giving off the four or five bristles. *There are now five rows of indistinct black spots, along the body, like those so distinct in Samia cynthia,* but they are not distinctly seen; those of the median row are somewhat diamond-shaped. One was observed while moulting, June 23. Length 15 mm., becoming 17 mm. The larva is more like *S. cynthia,* as directly after moulting it is yellowish, and the five rows of black spots are now very conspicuous, the median dorsal ones being more or less diamond-shaped; but the tubercles and spines are all black. The head is black, but pale on the labrum.

In this stage, just before moulting, it spins a floor of silk longer than its body, on which to stand, its crotchets being fastened in it during the process of exuviation.

On June 28, at 9 A. M., one had just moulted, having been seen to draw itself out of the crumpled end of its skin. All the tubercles of the two dorsal rows are amber-yellow, except those on the 2d and 3d thoracic segments, which are a little larger than the others, and deep orange. The four prothoracic and also the two lateral rows are pale greenish, without any flesh tints. At this time both the head and the prothoracic segment are entirely pale greenish yellow, and the body is deep yellow, like that of *S. cynthia,* with the black spots very conspicuous; all the spines, however, on all the tubercles are black. The tubercles * are now much stouter than before, *but are not yet spotted on the sides with black, as they are later in this stage.* Its length soon becomes from 18 to 20 mm.

Half an hour later (9.30 A. M.) it had not changed, but by 11 o'clock A. M. the four prothoracic tubercles (rather, however, three, as the inner one on the right side is wanting, another malformation) and the 2d or lower lateral row had turned dark, while the upper lateral row had begun to turn dark at the base. The black patches on the sides of the dorsal tubercles had also begun to appear; also the region at the base of the antennæ, as well as the clypeus and labrum, had turned pale.

At 12.45 P. M. the black tints became more pronounced. The prothoracic spines had all turned, as well as the two lateral ones, except those on the 6th abdominal segment, which were still pale at the end. In the 1st or upper lateral row the tubercles were pale at the end. Of the two dorsal rows, those of the abdomen are lemon-

* One tubercle on the left side of the 3d abdominal segment has no spines, a malformation never before observed.

yellow, and dusky at base, the two on the 9th segment being pale sea-green, with a black patch or band on the side extending around behind. The double large median tubercle on the 8th abdominal segment is now lemon-yellow, like those in front, with a large trapezoidal black patch on the posterior half, which does not reach up as far as the origin of the black spines. The spiracles are ringed with black.

By 3 P. M. all the dark portions and markings had become jet-black; there are now ten black spots on each segment, and the larva had now attained a length of 18 mm.

Stage III. — Length 20 mm. The following is the description of this stage when fully completed, and the color of the markings fully established. The head is black, with the clypeal and labral regions green, while an irregular green band passes back from the labrum above the eyes to the side of the head, the latter being now about two thirds as wide as the body. The larva is cylindrical, the tubercles are high and thick, the longer bristles being as long as the tubercles themselves. All the prothoracic tubercles are black; the two dorsal ones on each side being united by a black shining bridge at their base. The tubercles of the 2d and 3d thoracic segments are now deep coral-red, with black bristles; they are larger than the abdominal ones, and are very showy. The two dorsal rows of abdominal tubercles are lemon-yellow with black spines, and black at the base behind and on the sides. The single median spine on the 8th segment is nearly twice as thick as the others of the same segment on each side. The two lateral rows of tubercles are black, *with the ends of a beautiful pale blue*, approaching lapis-lazuli. There are a median and two lateral rows of black spots, situated between the spines; the median dorsal series consists of two spots, one in front of the other; while the spiracular series consists of two, one in front, and the other behind, but lower down than the spiracle. In some examples the body is yellowish.

The thoracic legs are black; those of the abdominal region green, but shining black on the outer side; the anal legs with a shining black patch nearly covering the outside of the leg. In one example the tubercles are aborted on the left side of the 2d and 3d thoracic and the 1st abdominal segments.

Stage IV. — July 12, one had just moulted, the end of the body having just been withdrawn from the cast skin at 11.10 A. M. Length 25 mm. The head and prothoracic segment are green, while all the prothoracic tubercles and those of the subdorsal and infraspiracular

rows are a beautiful pale cobalt-blue. The two dorsal tubercles of the 2d and 3d thoracic segments are deep orange (afterwards becoming coral-red); the homologous dorsal abdominal ones, including the single median one on the 8th segment, are lemon-yellow. The body is tinged with blue, especially on the thoracic segments. The spiracles are white with a fine black circle, and contain a straight linear central mark. All the bristles are still long, radiated, and are black.

In this stage the four dorsal tubercles of the 2d and 3d thoracic segments are larger than any others on the body; and those on the first seven abdominal segments are of nearly uniform size; the single one on the 8th segment being nearly twice as thick.

In this stage the eight to ten black dorsal and lateral spots dwindle in size, becoming less conspicuous; but the black spots on the side of the head and on the sides of the abdominal legs are large and distinct.

Stage V. and last. — Length 40–45 mm. One which moulted about the 9th of July had a pea-green head and prothoracic segment; the head marked with a roundish black spot on each side, below which is a large black patch bearing the ocelli, and lower down a black spot. The body is pea-green, washed with cobalt-blue along the back, beginning with the 2d thoracic and ending with the 8th abdominal segment, *and the black spots along the back and sides have disappeared.* Of the lowest lateral row of five small tubercles, the three thoracic and those on the first two abdominal segments are black; those on the third and fifth are blue at the end, but the bristles are black. All the prothoracic, and the two rows of lateral (the subdorsal and infraspiracular) tubercles are cobalt-blue. The two dorsal tubercles of the 2d and 3d thoracic segments are deep coral-red; the corresponding ones on abdominal segments 1 to 7, and the single one on the 8th segment, are lemon-yellow.

The spiracles are now white with a narrow black ring, but no central dark line. The thoracic feet are green, but black at the end. *The black spots on the sides of the pea-green abdominal feet are now obsolete*; the plantæ are bluish.

July 25–26. Some individuals were observed while moulting into the last stage, their length after exuviation being 47 mm.; they became after feeding still larger. This stage differs from Stage IV. in *the tubercles on the first abdominal segments being much larger and more spherical than before, and orange rather than yellow,* and thus in size, color, and the spines being more like the four coral-red thoracic tubercles than the other dorsal abdominal ones.

On the 1st abdominal, as well as the thoracic round-headed tubercles,

there is a circle of eight black flattened knobs representing the circle of spines above at the end; also the black spines on the median 8th abdominal tubercle are much shorter and stouter than before, as are all the spines on the other tubercles.

In all the five larvæ, except one, and in those of both stages (IV. and V.) the rows of black intertubercular spots have disappeared, the one retaining them (40 mm. long) having a single row of ten dorsal black rounded spots, two on a segment, along the abdomen.*

On the inside of the base of the infraspiracular row of turquoise-blue tubercles is a black spot, wanting on the 3d thoracic, but present on the 2d thoracic tubercle.

Recapitulation of the more Salient Ontogenetic Features.

A. Congenital Characters.

1. The setæ in Stage I. blunt, slightly bulbous, and glandular.
2. The tubercles are all of the same size.
3. Body in Stage I. dark, almost blackish, green, head jet-black; tubercles yellowish green.
4. The homologue of the "caudal horn" shows plainly its double origin.
5. The difference between the colors of the larva of the first and last stages very marked.

B. Evolution of later Adaptational Features.

1. The thoracic dorsal tubercles in Stage II. and onward are longer than the abdominal ones.
2. Five rows of indistinct black spots along the body in Stage II., not so distinct as in *S. cynthia*, the body being still dusky green. (These do not originate from lines.) At the end of Stage II. the larva is more like *cynthia* of the same age, the body being more yellow, and the black spots more distinct. The spots disappear at the end of Stage IV.
3. The thoracic dorsal tubercles deep orange; their homologues on the abdominal segments amber-yellow.
4. The tubercles at the end of Stage II. and in Stage III. spotted on the sides with black.

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* This larva wants the right 3d thoracic tubercle, and also the right 2d abdominal one. In another larva of the same stage the right 1st abdominal tubercle is partly atrophied, half the normal size, and with only two or three rudimentary spines. These tubercles and their spines in confinement are apt to be atrophied from disease; this also occurs in *S. cynthia* and *T. polyphemus*.

5. In Stage III. the dorsal tubercles of 2d and 3d thoracic segments showy coral-red. The subdorsal and infraspiracular tubercles tipped with pale blue; in Stage II. the same tubercles are almost entirely pale blue.
6. The head becomes green in stage IV., with a black spot on the side.
7. The larva is most gaudily colored and conspicuous in the last two stages; while in *S. cynthia* there are not so marked differences between the different stages, though the last is the most variegated owing to the beautiful turquoise-blue trappings.

NOTE ON THE FRESHLY HATCHED LARVA OF PLATYSAMIA GLOVERII.

Young Larva, just hatched. — May 15. Just as it slips out of the egg the body and head are jet-black, but the spines are white, though their tips at the origin of the hairs are black. In a few moments, however, the spines turn jet-black; the hairs arising from them being white.

NOTE ON A YOUNG PLATYSAMIA LARVA FROM ARIZONA.

I have had an opportunity, given me by Dr. Riley, of examining several freshly hatched larvæ from Arizona, in the collection of the U. S. National Museum (No. 3053, box 13.75). They seem to be congeneric with *P. cecropia*, but differ in the following respects. Head black, body darker, the spines dark towards the end. The spines are of the same general shape, but the trunks are a little shorter and thicker, more stumpy, while the bristles arising from them are a little longer.

As *Platysamia polyommata* Tepper is the only species from "Southern Arizona," it is perhaps the young of this form, but more likely is *P. gloverii*, as I possess the mature larva of this species collected by the Wheeler Survey party on the Sierra Amarilla in New Mexico. It only differs from another fully fed larva of this species from Salt Lake City in having all the spines slightly slenderer.

THE LIFE HISTORY OF CALLOSAMIA PROMETHEA (Drury).

The larvæ are at first gregarious, feeding side by side on the under side of the leaf.

Egg. — Oval-cylindrical, somewhat flattened; the surface pure white, somewhat shining. Under a half-inch objective the shell at first

seems to be entirely smooth and shining, without any markings, with neither pits nor polygonal areas, but after further observation very faint, irregular, moderately large polygonal areas, with faintly raised edges or boundaries, can be detected. Length 1.8, breadth 1.5 mm.

The egg of *C. angulifera* is the same as *C. promethea* in shape and color, though mine are slightly smaller, and the polygonal markings appear to be even fainter than in *C. promethea*.

In the Attacinæ the eggs present generic, specific, and perhaps varietal characters; this of course depends on the structure of the lining of the oviduct, and it may be asked what natural selection or the influence of external surroundings have to do with the differences in the shape, structure, and markings of eggs.

Larva, Stage I. — Described a few hours after hatching. Length 5 mm. The head is wider than the body in the middle, and as wide as the prothoracic segment; black, with a broad transverse whitish band crossing the clypeus, including the apex and a large portion of the clypeus itself, the labrum and base of the antennæ pale. The thoracic tubercles, at first lemon-yellow, become afterwards dusky greenish, while those of abdominal segments 1 to 7 are lemon-yellow; all give rise to black bristles, the longer of which are *about twice as long* as the tubercles themselves, being much longer than in the other Attacinæ of the same stage, while the tubercles themselves are smaller in proportion. The thoracic tubercles bear seven or eight, and the abdominal six bristles, one of which is often longer than the others.

The body is lemon-yellow, very conspicuously banded crosswise with black. The prothoracic segment is yellow; dusky along the front edge; or yellow with one or several black spots; on the hinder edge is a broad black transverse band ending on the lowest lateral tubercle, which is yellow, and a little larger than the dorsal ones on the same segment. The front and hinder edges of each succeeding segment of the body are black. The anal legs have a large black spot on each side. The three tenant setæ on the thoracic feet are broad and lancet-shaped, and there are 16 crotchets on the abdominal legs.

The single median tubercle on the 8th abdominal segment is evidently double in its origin, being twice as broad as long at the base, and there is a median space between the two sets of setæ, there being two tops or crowns, from each of which arise five setæ; and it is larger than the others, its greatest diameter being the transverse one. This and the two dorsal and lateral tubercles on the 9th and 10th segments (suranal plate) are dusky or blackish green, and are of the same hue as those on the thoracic segments, and *they are a little larger* than

those on abdominal segments 1 to 7, those being yellow. All the bristles are jet-black, and there are none of any other color. They are finely spinulated, the spinules rather dense; they taper to the acute end, and are clear and probably glandular. It is to be noticed that the body is transversely banded with black ; that the dorsal tubercles of the three thoracic and the last two abdominal segments are already in this stage differentiated in color and size from those of the first seven abdominal segments ; indeed, the larva is much variegated, being showily banded, with great contrasts of color.

Mr. Bridgham's specimens of Stage I. were observed on July 15, and were fed on the sassafras and wild cherry. The second stage was drawn on July 23d.

Stage II. — Length 10 to 12 mm. The head is not quite so wide as the body behind the middle, being much smaller in proportion to the body than before ; it is black, with a sinuous broad conspicuous *whitish* (not yellow as in Stage I.) band passing across the clypeus, so as to include the apex, and curving down towards the antennæ. The ground color of the body is *whitish* instead of yellowish, so that the transverse black bands, though narrower, are more conspicuous than before. On the 1st thoracic and 9th abdominal segments are two dorsal and two lateral black tubercles, one as in Stage I., but on all the other segments except the 10th abdominal the tubercles are now yellowish with black spines ; all the tubercles are situated on the white portion of the body, the black bands being situated between them. The single median tubercle on the 8th abdominal segment is now *yellowish*, and distinctly seen to be double, being very broad, and each side provided with a crown of about five spines. There are five or six spines to each tubercle, and many *are black, and much shorter and stouter than in the previous stage*, the outer ones being about as long as the tubercles bearing them are high, the central inner one longer. The round black spot on the side of the anal leg differs from that in Stage I. in being curved, boomerang-shaped. The thoracic legs are black, and the abdominal ones pale yellowish. *In this stage the dorsal tubercles on the 2d and 3d thoracic segments are of the same size and color as those of abdominal segments 1 to 7 ; the differentiation in size and color of the four thoracic tubercles having not yet taken place.* It is to be observed that in Stage I. the dorsal tubercles on all these thoracic segments are black, and the median one on the 8th abdominal segment is also black.

Bridgham's figure and Riley's specimen, from which the foregoing description has been drawn up, agrees with Riley's description.

Figure 4 (Plate I.) represents a dorsal view of the last four abdominal segments (VII.–X.) with the medio-dorsal tubercle (d') on the eighth uromere (VIII.), bearing ten setæ, two of them arising one on each side of the median line; *a*, a seta from one of the dorsal tubercles on the 9th segment; *b*, one from the 7th segment showing the medullary fluid supposed to be the poisonous secretion, though there is no secretory cell visible at the origin of the spine; the spine is dark and rather opaque.

Stage III. — (Described from an alcoholic specimen in the author's collection.) Length 15 mm.; width of head 2 mm. The head is marked in general as before, but the hairs are smaller and less numerous. *The sinuous white band in front is much wider than before,* being in front fully *three times as wide as the black line* connecting the eyes; the band being narrower on the sides above the eyes. The head is much narrower than the body, which is now stout and thick. *The two transverse black bands or rings on each of the thoracic and abdominal segments have now disappeared,* only faint traces of them being left here and there, the most persistent traces being a minute linear black spot situated on the side behind the spiracles. The prothoracic tubercles are black, and about half as long and large as the 2d and 3d thoracic dorsal ones, which are whitish, with a black ring at base; the lateral ones being black-brown. *All the dorsal abdominal tubercles are but a little smaller than the thoracic ones, and all, both dorsal and lateral, are black-brown,* except the single large dorsal tubercle on the 8th segment, which is now very large and fully twice as thick as the largest dorsal ones elsewhere, if not more; it has four spines on each side, and two central ones. In all the tubercles the spines are now short, and no longer than the thickness of the tubercles bearing them. The black curved line on the side of the anal legs is now *more curved than before.*

Stage IV. — (Described from Mr. Bridgham's colored sketch.) Length 20 mm. *The head is now yellow,* with two black dots in front, and a narrow black transverse line connecting the eyes and antennæ; the head is about two thirds as wide as the body, which is now whitish. The tubercles on the prothoracic segment are black, and of the same size as those on the abdominal segments, *the latter (dorsal ones) being now about one half as long and large as those on the 2d and 3d thoracic segments;* the single median dorsal one on the 8th segment being a little thicker, and colored sulphur-yellow (Riley), like those on the 2d and 3d thoracic segments.

The curved black line is slenderer than in Stage III. All the legs, both thoracic and abdominal, are pale yellowish.

Stage V. and last. — Length 45–50 mm. In its final shape, the body is cylindrical, tapering towards each end, and not so stout and thick as in Platysamia, or Telea, or Actias, or Attacus, and the tubercles are smaller, smoother, and without the conspicuous large spines present in the genera named, while the dorsal abdominal tubercles are smaller than in any other genus of Attacinæ known to us. In its larval characters the genus is the last and most specialized of a series beginning with Saturnia (*S. carpini*) and including Platysamia and Samia.

The head is small, being a little less than one half as thick as the body, and now is without any black spots. The black dorsal prothoracic and abdominal tubercles *are much shorter than in Stage IV.* The dorsal prothoracic ones are mere black spots, not even rising into low warts; the two lateral ones on each side are much larger than the rudimentary dorsal ones, rising into low conical shining black tubercles no higher than wide. The homologous lateral tubercles on thoracic segments 2 and 3 are larger and more prominent than those on abdominal segments 1 to 7. The rudimentary black dorsal tubercles on abdominal segments 1 to 7 are low rounded conical shining black bosses, which are transversely oval at base, and not so high as wide. The four dorsal 2d and 3d thoracic tubercles, together with the single median one on the 8th abdominal segment, are all of the same size seen sideways, but the last named tubercle seen from in front or behind is thicker, owing to its double origin. The two dorsal ones on the 9th abdominal segment are rather high, being long, conical, but no higher than the median single one on the 8th segment. All the legs are yellowish; each of the middle abdominal legs with a black dot in the middle of the outer side.

Professor Riley has briefly described and in part figured in his Fourth Missouri Report (p. 121) the five stages of this larva; and my material confirms his description. Mr. Dyar, however, claims that from his observations there are but four stages. For the colors, since we have not yet seen the living larva, we must quote from Riley, who states that in the fifth stage "the appearance is totally changed; the body is of a most delicate bluish white, with a faint pruinescence." Further on he says: "As this worm acquires its full growth, the pruinescence mentioned above disappears, and it acquires a more greenish cast, except around the base of the tubercles, where there is a more decided blue annulation." In Psyche for June, 1891, M. Beutenmüller gives a detailed description of *six* stages, *five* moults. His fifth and sixth stages appear to be the same as our fifth.

THE LIFE HISTORY OF CALLOSAMIA ANGULIFERA (Walk.).

The larvæ hatched on July 6 and 7 from eggs kindly sent me by Miss Morton, and fed on the leaves of the tulip tree, Stages II. to IV., are described from Mr. Bridgham's colored figures. Miss Caroline G. Soule describes the five stages in Psyche, Vol. V. p. 260.

Egg. — Of the same shape and color as those of *C. promethea,* though slightly smaller, while the polygonal markings appear to be even fainter than in *C. promethea.*

Freshly hatched Larva. — Length 4 mm. The head is black, with two lunate ochreous yellow spots on the vertex, while in front, on the middle, is a transverse, pale parchment-colored stripe, and in front of this stripe is a transverse clypeal line of the same pale hue. The body is pale ochreous yellow, and the hairs appear to be of the same color; the two faint transverse lines on each segment being nearly obsolete, so that in some specimens they are not apparent, and the body does not appear to be striped with black, as is so plainly the case in *C. promethea.*

Compared with *C. promethea* of the same stage, the larvæ of the present species are rather smaller, and differ decidedly, the body being much paler, and not heavily striped with black, the transverse black bands, so broad and deep black in *C. promethea,* being much narrower, very much fainter, and often nearly obsolete; also all the tubercles and hairs, except those on the prothoracic and sometimes the 10th abdominal segments are pale yellowish, like the body. The tubercles and setæ on the prothoracic segment are not so dark as in *C. promethea.* The upper pale stripe on the head is a little narrower than in *C. promethea.* The black stripes on the last three abdominal segments are somewhat heavier than those in front. The tubercles on the 9th abdominal segment and the end of the anal or 10th segment may be dusky, while the dark stripes on the segments in front may be entirely wanting.

There is little difficulty in separating the larvæ of the two species at the first stage. It is noteworthy that the colors of the dorsal tubercles are not so much differentiated as in *C. promethea,* or they are in a degenerate stage; the dorsal tubercles of the 2d and 3d and the 1st and 7th to 9th abdominal segments are not dark, as in *C. promethea,* but like those on segments 2–6. The dorsal tubercles are a little slenderer, and the setæ or hairs rather longer, than in *C. promethea.* The tubercles have the same number of setæ as in *C. promethea,* the single one on the 8th abdominal segment having ten setæ, and being distinctly

PLATE II

7

8

5

ARMATURE OF ATTACINE CATERPILLARS.

divided into halves. There is no black patch on the side of the anal legs, it being well marked in *C. promethea*, and the thoracic feet are considerably paler.

This stage was drawn at Providence, July 8; the 2d, July 13; the 3d, July 15; the 4th, July 19; the 5th, July 26; the larva becoming fully grown August 1.

Figure 5 (Plate II.). The last six abdominal segments (V.–X.) of *C. angulifera*, which should be compared with the camera drawing of the same parts in *C. promethea* to show how different the shapes of the tubercles are, the setæ also differing in the two species at the same stage. The setæ on the suranal plate have not been drawn. The setæ are transparent. *d'*, homologue of the "caudal spine" of Sphingidæ. *d*, a seta enlarged.

Stage II. — Length 8 mm. The body is now longer in proportion than before, and the head is now no wider than the body. The head is black, and striped with whitish yellow, the shape and width of the pale stripes nearly as in Stage I. The prothoracic segment has black dorsal tubercles, and the black transverse dorsal band is divided into two patches, situated behind the tubercles. The tubercles are now shorter than before, with shorter bristles, and those on the 2d and 3d thoracic, and the 1st, 8th, and 9th abdominal segments, are slightly, but not very noticeably, larger than before. The larva differs markedly from that of *C. promethea* of this stage in the faint, narrow transverse stripes, those of *C. promethea* being still heavy and dark. There is no curved black spot on the side of the anal legs; the thoracic legs are much paler than in *C. promethea.* The body is greenish yellow, while the ground color of *C. promethea* is more of a whitish hue. Only the two last abdominal tubercles (on 10th segment) are dusky. (The figures of Mr. Bridgham agree with Miss Soule's description.)

Stage II. — Length 12 mm. The head now differs in being less black, the pale bands being wider, and there are two white spots on the vertex, one on each side. The body is pale straw yellow, more distinctly banded with black than before, the two heaviest and broadest bands being on the hinder edges of the prothoracic and the 8th and 9th abdominal segments, while the suranal plate is blacker than before, with a lateral black line. On the other segments, the black bands (two to each segment) are confined to the back, and do not extend down the sides. All the tubercles from the 2d thoracic to and including the 9th abdominal ones are yellowish.

At the end of this stage, length 18 mm. The body is rather thicker

than before, and whiter yellow; the head with more white, especially on the vertex, and the white stripe across the middle is rather wider. The 2d and 3d thoracic, 1st, 8th, and 9th abdominal dorsal tubercles are not distinctly larger than the others, and all are paler. The black stripes are nearly as before, but perhaps not quite so heavy. The suranal plate is not so black as before, but with two black spots; and *on the side of the anal plate is a black elongated patch.*

Stage IV. — Length 34–35 mm. The characters of the fully grown larva are now nearly attained. The head is large, three fourths as wide as the body, pale lemon-greenish, with six black dots, two below, and one above. The two dorsal prothoracic tubercles yellowish; the lateral ones black. The two dorsal tubercles on the 2d and 3d thoracic segments are now high, large, and with obsolete spines, red, with a black base or ring (Miss Soule says, "black at base, ringed with yellow, orange at tips, smooth"). The single one on the 8th abdominal segment is ringed with black at the base, and beyond yellow; it is slightly smaller than those on the thoracic segments. All the other dorsal as well as lateral tubercles are now reduced to low small black rudimentary tubercles. In this stage it differs from that of *C. promethea* of the same stage in the much shorter black tubercles on the 2d to 7th abdominal segments; and in the dorsal tubercles on the 2d and 3d thoracic segments being reddish, instead of yellowish. The curved horseshoe-shaped black line on the side of the anal legs is the same as in *C. promethea.* The "yellow stigmatal ridge" noticed by Miss Soule is shown in Bridgham's figure.

Full-grown Larva. — Length 68 mm. On comparing a blown specimen of *C. angulifera* with one of *C. promethea* the former differs in the following particulars. The head is slightly larger, without the two black dots in front and the lateral dot, and without the broad black stripe extending in *C. promethea* from each side of the base of the labrum upward, and ending on the side of the head below the lateral dot. The four dorsal black spots on the prothoracic segment are wanting in *C. angulifera,* and the short lateral tubercles are not colored black as in *C. promethea,* while the tubercles themselves are much smaller and less prominent. The four dorsal tubercles (two on the 2d and two on the 3d thoracic segment) are decidedly smaller and slenderer than in *C. promethea;* the tips are black where those of *C. promethea* are yellow, and the black ring around the base is narrower than in *C. promethea.* The two lateral small black tubercles on each of these segments are wanting, and all traces of them have nearly

or quite vanished. Of the dorsal ones I can with difficulty, by means of a good lens, find faint traces, they are so nearly effaced.*

There are in *C. angulifera* no black spots on the base of the four pairs of middle abdominal legs, and there is a black ring only on the lower side of the anal legs, as in *C. promethea.* The suranal plate has two transverse linear black spots on the ends, but none of the other black markings of *C. promethea.* It wants the pair of triangular black sternal spots situated in front of each pair of thoracic legs of *C. promethea.* The median dorsal horn on the 8th abdominal segment is black at the base and tip. The two dorsal black tubercles on the 9th segment, and the lateral ones, are wanting, though they are conspicuous in *C. promethea.*

C. angulifera is much duller in color and much less ornamented, with shorter, less conspicuous tubercles, and all, both dorsal and lateral, on abdominal segments 1 to 7 are wanting. It seems to be a form which may be regarded as having originated later than *C. promethea,* and which has diverged from it, and it seems to be a species which has directly evolved from the stem-form *promethea.*

Recapitulation of the more Salient Ontogenetic Features of Callosamia.

A. *Congenital Features.*

1. Hatched with heavy black transverse bands on a yellow body, and the head black, banded with yellow; the bristles moderately long; thus the larva is already a rather conspicuous object.

2. The dorsal thoracic tubercles already differentiated in size and color from those on abdominal segments 1 to 7. The differences between the freshly hatched larva and the last stage very marked; more so than in Platysamia or Samia.

B. *Evolution of later Adaptational Features.*

1. In Stage II. the body becomes paler, and thus the black bands more conspicuous. The 2d and 3d thoracic dorsal tubercles and those on abdominal segments 1 to 8 are now all yellowish, and of the same size.

* These tubercles have evidently disappeared owing to disuse. What there is in its habits to bring this about is a matter of conjecture; this form is only known to feed on the tulip tree, and this may be a case of arboreal selection; the change of food plant, together with possibly the abundance of food, this tree having but few species of larvæ feeding on it, may have had something to do with the abolition of the tubercles.

2. Disappearance in Stage III. of the transverse black bands. The abdominal tubercles all become blackish.

3. In Stage IV. the head becomes yellow, being less conspicuously marked, and the dorsal abdominal tubercles are about half as long and large as those on the 2d and 3d thoracic segments.

4. The body becomes in the last stage much smoother than before, the dorsal prothoracic and abdominal tubercles being much shorter than in Stage IV. This reduction of size and inconspicuousness of the dorsal abdominal tubercles is carried out to excess in *C. angulifera*, where they become obsolete, and the larva is simply a large green caterpillar with inconspicuous markings, and simply protected by its green color, like the majority of lepidopterous larvæ; not being so strikingly marked as in the fully fed *Samia cynthia*.

The Life History of Samia cynthia (Drury).

The eggs were received from Mr. H. Meeske. The larvæ were at first fed on the leaves of the ailanthus, but when transferred to Brunswick, Maine, ate freely of the wild plum.

The Egg. — Regularly oval-cylindrical, dull chalky white; the surface of the shell finely pitted, but not arranged in wavy rows as in *P. cecropia*; the pits under a half-inch objective are near together and slightly polygonal, and their walls project as little bosses on the inside of the shell. Length 2 mm., thickness 1.4 mm.

Larva, Stage I. — Hatched June 11. Described one day after hatching. Length 4–5 mm. Head rather large, as wide as the prothoracic segment. The body gradually tapers from the head to the tail, and is of a pale greenish yellow, the head dark chestnut, with a pale greenish clypeus and labrum. The prothoracic segment is broad and somewhat flattened above, with a dark chestnut-colored chitinous plate or squarish patch on each side, sometimes appearing as widely separated by a pale greenish yellow clear median dorsal space; with four dorsal and two lateral black tubercles; of the dorsal ones the two in the middle are slightly larger than those outside, and larger than the lateral ones; they are also connected at their base by a slight ridge. All the tubercles are much alike on all the segments, bearing from 5 to 7 setæ, those on abdominal segments 5 to 7 scarcely smaller than those on the thoracic. The hairs or bristles are whitish, or rather colorless, 4 or 5 to 7 on each dorsal tubercle; they are slender, not stiff or thickened at base, and are spinulated, the spinules short and acute; under a half-inch objective they appear, not bulbous, but tapering, and being transparent may be glandular.

The single median tubercle on the 8th abdominal segment is sometimes nearly twice as large as the others on the same segment, and is double, being broader than long, bearing four bristles on each side.

There are two setiferous tubercles on the 9th abdominal segment, and, as generally in the group, two short but large ones on the 10th, being situated on the front edge of the suranal plate, and bearing each eight bristles. All the tubercles on the body are jet-black.

The spiracles are pale, and inconspicuous. The thoracic feet bear three lancet-shaped tenant hairs, but they are a little wider than those of *P. cecropia*. The abdominal feet bear fourteen crotchets.

Before the first moult the larvæ increase in size and length (7–8 mm.), becoming much fuller, swollen out with food; the body, however, is smooth, the segments not being swollen; it is bright straw-yellow; the spines are not so long as before, and the bristles are considerably shorter. *A dorsal row of dark spots is present.*

Before a change of skin the larva rests immovably for several hours, the membrane in front of the prothoracic segment being swollen between the head and the front edge of the segment, and the head, now appearing to be very small in proportion to the swollen prothoracic segment is held downward, while the thoracic feet are stretched forward. In moulting it leaves behind it only a small mass of crumpled skin, as the cuticle is so thin.

Figure 6 (Plate II.), *a*, dorsal tubercle on 2d thoracic segment; *b*, the same on the 3d thoracic segment; *c*, a subdorsal tubercle of the 7th abdominal segment; *d*, a seta; *d'*, *d''*, ends of two others. All Stage I. Drawn with the camera.

Stage II. — One had just moulted, June 17. The body was all yellow except the dorsal and two lateral rows of black spots between the rows of tubercles, there being two spots in each row on each segment. All the tubercles are now amber-yellow, and the hairs are pale.

An individual was noticed to increase in length soon after ecdysis. It was observed at 4.20 P. M. In about twenty minutes or half an hour after moulting, when it is 9 to 10 mm. long, the tubercles on the side, especially those in front, begin to turn dark, the thoracic ones first changing color. In about an hour an obscure broad dusky band crossing the head appears; in fifty minutes or an hour, the thoracic legs have turned blackish, and by this time the creature begins to eat, this species feeding well in confinement. In an hour and a half the lower lateral (infraspiracular) row of tubercles and those on the 10th abdominal segment had turned black, but the upper lateral and dorsal ones were still pale. By 6.30 P. M. the others, both dorsal and lateral,

had become dark at the tips, but the hairs were still pale. About a day later, i. e. at 5 P. M., the tips of the tubercles only were dark, the bases being still pale yellow as before.

This stage differs but little from the first, chiefly in the *pale honey-yellowish head;* there are as yet no differences in the size of the dorsal tubercles, though they are in this stage *pale yellowish at the base,* where before they were black throughout.

Stage III. — They moulted again, June 22–23. Length 14–15 mm. The body is of the same yellow hue as before, the tubercles at first being all yellow. The lateral ones are the first to turn dark. The head is pale yellow, concolorous with the body.

In the preceding stage, on each abdominal segment there is an upright faint short blackish stripe behind the spiracle; in the present stage there is a jet-black stripe, which is somewhat curved or excavated on the front edge; there is none on the prothoracic segment, and the stripe is represented on the 2d and 3d thoracic segments by an irregular black rounded dot. At the base of the thoracic legs is a black dot, not present at the base of the abdominal legs. The tubercles are nearly of the same shape and relative size as in Stage II., *but the six dorsal and four last abdominal (the dorsal ones on 9th and 10th segments) are slightly larger than the other abdominal ones,* while the spiracles are larger than before and black; the other black marks are as before.

Stage IV. — One moulted again the morning of July 1. Length 15–16 mm., one 20 mm. and eventually becoming 25 mm. When observed an hour or two after casting its skin, the body as before was pale lemon-yellow; the tubercles of the same color as before, i. e. pale greenish yellow, except those of the lower lateral row which are black on the trunk, but with the head or end and the spines light greenish yellow. The dorsal and two lateral rows of black spots are as before. The head and upper side of the prothoracic segments are shining honey-yellow, *as is also the 9th and 10th abdominal segments, while the body is covered with a whitish mealy bloom.*

The larvæ, which were reared in Brunswick, Maine, from eggs laid in Brooklyn, seem to feed sparingly and to grow slowly, and were fed at first with ailanthus, and afterwards with wild plum. They became before moulting again very white, *the bloom being thick and powdery, so that the honey-yellow head and prothoracic plate, with the suranal plate, together with the sides of the anal legs and upper part of the 9th abdominal segment, contrast with the color of the body.*

In this stage the two anterior setiferous tubercles on the suranal plate are still well developed, as are also their bristles.

Stage V. — Moulted July 15–18. Length 40 mm. It differs from the preceding stage in the rarely beautiful *pale turquoise-blue edging on the edge of the suranal plate and anal legs, and in the pale bluish tint on the ends of all the tubercles, and at the base of the middle abdominal legs.*

The head is lemon-yellow as before, about one half as thick as the body, and is bluish on the region of the eyes. The prothoracic segment is lemon-yellow, edged with pale blue, while the tubercles are of a beautiful pale turquoise tint. The tubercles are still long and slender, those of the thoracic and last two segments scarcely larger than the others.

In this genus the tubercles are remarkably long, with short, small, pale radiating bristles, much shorter and slighter than in Platysamia.

The suranal plate also in Stage V. *bears two low bosses without bristles* (only their rudiments), while in *P. cecropia* these tubercles with their bristles are well developed; it also differs in the black spots of the last stage.

Those of the dorsal and subdorsal rows are pale whitish green at base, passing towards the end into pale turquoise-blue. The infraspiracular row of tubercles are ringed with black at the base. The black spots on the body are as in the previous stages. The thoracic and abdominal legs are lemon-yellow, the latter pale bluish at base and on the planta. The suranal plate and dorsal region of the 9th segment are lemon-yellow, the thickened much swollen edge of the suranal plate is turquoise-blue, including the tubercles, and the edge of the anal legs is of the same tint, the blue suddenly expanding on the lower side above the crotchets.

In this stage the body in general is turquoise bluish white, rather than pure white or slightly yellowish white, as in Stage III.

August 20th one spun a cocoon, and the others stopped growing, perhaps partly on account of the cooler climate than their parents had experienced, though the season of 1890 was a warm one for Maine.

By the larval characters this Chinese or Eastern Asiatic genus is much more closely allied to Platysamia than to Attacus, though the imago perhaps has more of the habit and general form and appearance of Attacus. It differs from Platysamia in the rather slenderer body, the decidedly longer tubercles, and the slighter, shorter bristles arising from them, and in coloration by the pale lemon-yellow skin, with the conspicuous black spots, and the beautiful turquoise-blue markings, as well as the peculiar soft white bloom on the skin. How far this style of ornamentation adapts it to its native Asiatic food plant we do not know.

Recapitulation of the more Salient Ontogenetic Features.

A. Congenital Features.

1. Hatched with large, well developed setiferous tubercles; but the bristles not bulbous in Stage I.

2. The body pale, but the tubercles dark, and besides these intertubercular conspicuous black spots are present in Stages I. to V.

3. The homologue of the "caudal horn" is double, bearing four bristles on each side.

The difference between the larva of the first stage and the last, unusually slight compared with Platysamia and Callosamia.

B. Evolution of later Adaptational Features.

1. The tubercles become pale at tip in Stage III., and those of the two dorsal rows of the thoracic and last two abdominal segments become slightly larger than those of abdominal segments 1 to 7, in Stage III.

2. Differences in coloration appear in Stage IV., the head, prothoracic and last two abdominal segments being honey-yellow, thus contrasting with the whitish body, with its whitish bloom, which also appears in this stage.

3. Farther changes in color appear in the last stage, the ends of all the tubercles becoming pale bluish, and the edges of the suranal plate and anal legs being a rich turquoise-blue.

4. In the last stage a very slight difference in the size and shape of the thoracic and the last abdominal tubercle.

5. The tubercles on the suranal plate become reduced to low bosses, without bristles. Thus *Samia cynthia* is a decided step in advance of Platysamia, and appears to be a later formed genus.

Comparison between the Larva of Samia and Callosamia. — The fully fed larva of *Samia cynthia* is in the shape of the head and body, and in the shape of the tubercles with which the latter is armed, more allied to Callosamia than to Attacus, although the imago is perhaps as near the latter genus as to Callosamia. The head of the larva of Samia is almost identical with that of Callosamia. The nearly obsolescent tubercles on the prothoracic segment have about the same degree of degeneration in Samia as in Callosamia, but the former differs in the fact that the lateral tubercles in all three thoracic segments are well developed, and end in a head armed with four spines, as in Platysamia (*P. cecropia*), while the tubercles are as well de-

veloped on the abdominal segments as on the thoracic. The thoracic tubercles also are no more differentiated than the abdominal ones. Samia also differs from Callosamia in the twelve rows of black spots along the body. The larva of Samia is thus seen to be intermediate between Platysamia and Callosamia, but the moth is apparently intermediate between Callosamia (*C. angulifera*) and Attacus.

The head and the shape and size of the body of the larva are like those of Callosamia, but in its secondary adaptive generic characters it retains a resemblance to Platysamia. In a systematic classification, then, we had better adopt the imaginal characters rather than the larval, the latter being so much more plastic and more readily influenced by changes in the mode of life and by differences in the food. In its earliest larval stages, the insect is certainly more like *Platysamia cecropia* than Callosamia, but still even in these stages Samia is more advanced than Platysamia, which in its earliest larval stages, especially in the possession of long bristles arising from the short tubercles, intergrades with or is closely allied to the fully grown larva of *Saturnia carpini;* and in the imaginal characters Platysamia is nearer the ancestral form Saturnia (in the restricted sense) than to any of the other Attaci. If we do as we should do in locating Samia in its proper taxonomic position, we shall not err greatly in placing Samia much above Cecropia, and on the whole near Attacus.

Larva of Attacus sp. (possibly A. splendidus DeB.).

The larva of which I give the following description was collected at Socorro, Arizona, September 9, 1874, by Wheeler's Expedition. The single specimen was in alcohol. It is probably about half grown. (Plate II. Figure 7.)

Length 25 mm. Head rather large, slightly more than one half as wide as the body when it is thickest; it is of a chestnut color, smooth, not hairy. The body is moderately long and quite thick and fleshy, tapering rather rapidly behind. The prothoracic segment is granulated above, but with no tubercles; on each side, however, is a remarkably long fleshy tubercle or process, which hangs down and curls back like a ram's horn, and is finely spinulose; it is about as long as the segment is thick, and is situated exactly in front of the spiracle of the same segment. On each of the 2d and 3d thoracic segments is a pair of short thick tubercles, those on the 3d a little longer than those on the 2d segment. On each side of these seg-

ments is a long curled tubercle similar to those in front, but only a little more than one half as long; those on the 3d segment are shorter and thicker at the end, and a little more than one half as long as those on the segment in front. On each of abdominal segments 1 to 9 is a pair of similar tubercles or processes which increase in size and length from segments 4 to 9, those on 7 to 9 being of nearly the same size. On the side of each of abdominal segments 2 to 8, situated far below the spiracles and just above the legs where present, are similar horn-like processes, but which are longer than the dorsal ones on the 2d abdominal segment, whereas on segments 3 to 8 they are about the same size and length. All these processes are provided with short hairs. It is probable that some or all of them are more or less erectile.

This species is allied to the larva of *Attacus atlas* Linn., as figured by Horsfield and Moore in their Catalogue of Lepidopterous Insects, II., Pl. XX. Fig. 2. It differs, however, from the full-grown larva of that Asiatic species in the dorsal abdominal processes being shorter, and the lateral abdominal ones being much longer, especially on segments 4 to 9, while the thoracic ones are longer, especially the first pair next to the head. But the larva is of the same general shape, and undoubtedly is a true Attacus.

Attacus appears to be the only genus possessing these remarkably soft, long fleshy processes, which remind us of those of the Cochliopod Phobetron.

THE LIFE HISTORY OF TELEA POLYPHEMUS (Cramer).

The larvæ, usually feeding on the oak, have been found on the chestnut, and in Maine on the beech. Although so often raised, a full life history of this fine insect has not yet been published.

Egg. — Regularly oval-cylindrical, each end alike; flattened at each pole; surface chalky white, with a very broad, conspicuous dark brown band. Under a lens, the surface of the shell is seen to be finely pitted or granulated; under a half-inch objective, the surface is seen to be covered with round shallow depressions bordered with a well marked rim; these orbicular areas do not touch each other, there being quite wide spaces between them; they are arranged obliquely. Length of egg 2.6 mm., breadth 2.2 mm.

Larva, Stage I. — Hatched June 12. (Described when 20–24 hours old.)

The brood hatches all at once, or nearly so. Length 5 to 6 mm.

The head is large and full, rounded as usual in the family; as wide as or slightly wider than the body, i. e. the prothoracic segment, not taking into account the lateral tubercles. It is deep bright brick-red; the labrum, antennæ, and jaws yellowish. The body gradually tapers backwards from the head.

The body is of a soft, pale greenish yellow; the tubercles pale yellowish, contrasting with the color of the body. The prothoracic segment flares in front, the edge turning up and bearing two large dorsal tubercles which are double. The prothoracic tubercles are very prominent, projecting on each side, and are about twice as large as the 2d and 3d thoracic ones, and bear twelve bristles. These tubercles and those of the same series on the 9th abdominal segment are much larger than the intermediate ones. There is a slight differentiation in size and color of the dorsal tubercles, those of the thoracic and 9th abdominal segments being of the same size, and larger than those on abdominal segments 1 to 7, and also of a deeper yellow shade. The bristles are pale, those on all the thoracic tubercles, dorsal and lateral, a little darker than those on the abdominal segments, and darker at the tips. They are but little longer than the tubercles, and there are about six on each abdominal tubercle. Under a half-inch objective the bristles are seen to be not only docked at the tip, but the latter is slightly but distinctly swollen or bulbous, and sometimes containing an oval mass of the coagulated secretion.

The median dorsal tubercle on the 8th abdominal segment is as large as those on the thoracic segments; it is twice as wide as long at the base, *and is more deeply divided than in any other of our Attaci known*, very plainly showing its origin from two originally separate dorsal tubercles; *each fork is well developed, being about as long as thick*, and each bearing from 4 to 5 bristles.

All the tubercles of the 9th segment are very large, about as large as those of the thoracic segments. The suranal plate is large, nearly equilaterally triangular, and bears near the apex two tubercles, each of which gives rise to eight bristles; they are smaller in proportion, and nearer together, than those of *C. promethea.*

The prothoracic segment is pale yellowish in front, chestnut-colored behind, becoming blackish on the sides low down. At the base of the lateral prothoracic tubercles are three black rings. On the side of each abdominal segment 1 to 8 is *a pair of parallel black slashes*, situated between each of the upper and lower lateral tubercles; on the 2d and 3d thoracic segments they meet on the middle of the back as chestnut-colored stripes. On each side of the 9th abdominal segment

is a large pale yellowish amber tubercle.* In some individuals all the tubercles on the body are amber-yellow.

The thoracic and abdominal legs are pale greenish, with no markings. The thoracic feet bear near the ungues the usual three tenant hairs, which are long-lanceolate, and moderately broad. The number of crotchets on the abdominal feet is twenty-four, larger by eight than in the other Attacidæ observed.

June 17, they had become larger, fuller, and from 9 to 10 mm. in length. The body is of a beautiful soft glaucous green, the tubercles yellowish, those on the prothoracic segment tinged with reddish; the black-brown slashes on the sides of the body are still present, but narrower. They are voracious feeders.

June 19, at Providence. (Like Mr. Bridgham's second drawing, Stage II.) I have not seen them cast their skins, though they must have done so. They are now 11 mm. long. They still retain the black slashes. All the tubercles are yellowish; the body being of a beautiful glaucous green. In some individuals the lateral prothoracic tubercles are reddish.

Figure 8 (Plate III.). Dorsal view of the 8th to 10th abdominal segments of the larva in Stage I., showing the double tubercle (*d'*) on the 8th segment (VIII.), and the two separate dorsal tubercles (*d*) on the 9th segment (IX.), with the two subdorsal tubercles of this segment (*sd*), together with the suranal plate (X.) and its armature.

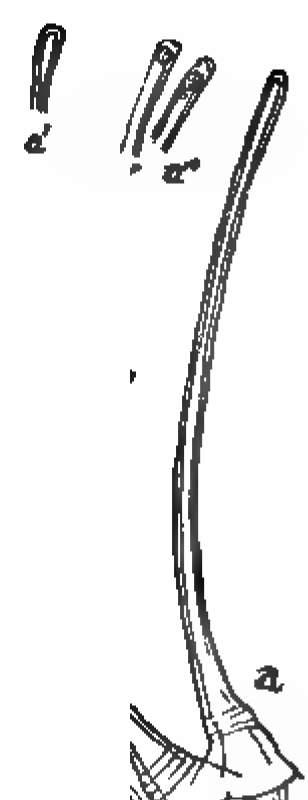
Figure 9. A view of the double dorsal tubercle (*d'*) of the same stage, showing the median line of union of what in embryonic life were probably separate dorsal tubercles, like those on the segments in front and behind; *m*, the muscles moving the setæ; *sd*, the subdorsal tubercles; *m*, the retractor muscles of the tubercle; *a*, one of the setæ, much enlarged, with the bases of two others; *a'*, *a''*, *a'''*, ends of other setæ, containing at the end globules of the medullary fluid. The setæ are seen to be smooth, without spinules of any sort. It is to be observed that in the double dorsal tubercle there are only four setæ on one side and five on the other, but five must be the normal number, and the number usual in the larvæ of the group at this stage.

Stage II. — June 23. Length 14 to 15 mm. They have most probably moulted, *the lateral pair of upright parallel slashes having*

* In *A. luna* the suranal plate is triangular, but slightly shorter than in *T. polyphemus*, the two tubercles are wider apart, not so near the end of the plate, and are much lower and flatter, while those of *T. polyphemus* are quite high and slender, papilliform.

PLATE III.

8



Armature of Attacine Caterpillars.

disappeared. The spiracles are now black and very distinct. The tubercles are deep orange at the end, the dorsal ones bearing mostly blackish bristles, with one or two white ones, those on the side of the body being pale; the lateral tubercles are orange, all the prothoracic tubercles deep orange, and the segment itself is edged with greenish yellow orange. The thoracic legs are deep orange; the abdominal legs green, tipped at the planta with yellow orange.

There is now *a lateral curved white band connecting the lateral tubercle on the 9th segment, with the corresponding one on the suranal plate.* Along the back and between the dorsal tubercles the skin has a soft glaucous bloom. The head is dark chestnut-red, as before.

In this stage the larvæ frequently assume a sphinx-like attitude, while those of *P. cecropia* and *S. cynthia* do not seem to, but these two species are in general more active, trying to escape from confinement.

Stage III. — Moulted July 1. Length 20 to 25 mm. The color of the head and tint of the body as before. The larva now differs in *the segments being more convex and angular*, or in transverse section somewhat square, somewhat as in the last stage. All the tubercles are alike in being pea-green at base, becoming deep reddish orange at the end, and bearing partly black and partly white spines or bristles, except the two median short tubercles on the prothoracic segment, which are yellow, and concolorous with the yellow margin of the whole segment. There are more white bristles on the abdominal than on the thoracic segments.

The spiracles are unusually narrow, being vertically almost linear, and orange-red, i. e. concolorous with the tubercles at the end, and now directly behind them is the *more or less distinct yellowish lateral slightly oblique stripe connecting the lateral tubercles of the lower and of the upper row*, and which touches each spiracle. (These were indicated, though less distinctly, in Stage II.)

The beautiful pale purplish whitish band or edging on the suranal plate, and connecting the two lower lateral tubercles of the 9th abdominal segment, is *now very distinct;* above, it is edged within with *a linear brownish line forming a* V, which does not reach the tubercles on either side, in fact only extends about half-way from the end of the suranal plate to the base. The median dorsal tubercle on the 8th abdominal segment is still plainly double, and larger than any of the others.

We thus have assumed in this stage the characters of the larva in its final stage.

The excellent differential characters separating this genus from other Attacinæ are now defined, and the same will apply to the larvæ of the third stage of Platysamia, Callosamia, and Actias, as well as Samia (Philosamia).

The following descriptions apply to two individuals specially observed during this stage.

One (A) in Stage II. was seen to cast its skin, July 5, at 11.15 to 11.30 A.M. The head was pale greenish yellow, like a peach, but without the reddish pink tinge. (*A. luna* appears to permanently retain the greenish tint.) The thoracic legs are greenish. All the tubercles are lemon-yellow, the short bristles on the thoracic tubercles black, those on the abdominal segments turning black. The long whip-like hairs are white. The V-shaped band on the edge of the suranal plate is a deep labradorite-azure. The lateral stripes are not yet very distinct. The spiracles are deep orange.

At 12.30 P.M. the head had turned almost chestnut-brown, and by 1 P.M. was of the normal dark chestnut-red hue.

Before casting its skin, it spins a thin carpet of silk threads, to which it clings with its crotchets while in the process of exuviation.

Another caterpillar (B) in Stage II. about moulting was first noticed at 11.30 A.M. The head was small, about half as large as in the next stage, pressed forward; the prothoracic segment above has a large yellow patch extending back to the next segment. The region is about half as wide as the whole segment, being that portion situated behind the two middle dorsal tubercles, and the brown membrane or neck connecting the head and the succeeding segment is tense. Now all the tubercles are deep orange-red, while there are no fine white hairs arising from the thoracic tubercles, and those arising from the abdominal tubercles are much shorter, nearly one half, than in the next moult (A). It fastened its crochets in the silk carpet it had spun previous to the beginning of the process of exuviation, so that the convulsive movements of the head and thoracic segments may not cause it to fall over while in the act of throwing off the old skin. The head is about one third, and almost one half, larger after moulting than before.

Now and then before the skin splits, and is cast off, the larva was observed to make a series of convulsive movements of the head and thoracic region.

It finally cast its skin between two and three o'clock P.M., and this individual looked like A when I first saw it.

This larva also was observed resting with its head and thoracic

region raised in a sphinx-like attitude, jerking its head sideways when disturbed. The pale chestnut face forms, with the folded thoracic feet, a continuous patch of color, of the same tint as that of the leaf buds, and the base of the leafstalks of the oak. In eating I do not see that the maxillæ and labium are of any service, but on the contrary seem to be in the way. Both are in lepidopterous larvæ rudimentary, and the labium in the main functions as a spinning organ.

Stage IV. — Moulted July 11–12. Length 40 to 45 mm. This differs but little from Stage III. The head is of the same color as in the three previous stages, and about half as wide as the body. The segments are rather more angular above than before. The prothoracic segment is yellow in front; the tubercles are small, and of the same yellow tint. All the other tubercles, both dorsal and lateral, are orange-red; *the dorsal tubercles have on the outside of the base, and extending nearly half-way up, a bright spot with a decided pearly color and lustre;* this spot is wanting on the infraspiracular tubercles. Most of the bristles are black broadly ringed with white, or white at the base, and on the distal half. The median dorsal tubercle on the 8th abdominal segment is still distinctly seen to be double, being bilobed at the end, each lobe or subtubercle bearing about four white setæ, one of them black.

Along the sides of the body project long white hairs. The spiracles are orange-brown, as before. The suranal plate is edged with flesh-pink, and the anal legs are bordered behind with the same smooth flesh-pink margin. The thoracic legs are reddish amber, black at their ends. The middle abdominal legs are green; the plantæ livid purplish; above the planta is a dark patch, bordered above with yellowish.

Stage V. — Moulted July 22–24. Length 60 mm. It now scarcely differs from the preceding stage. The silver tint on the outside of the base of the dorsal and subdorsal tubercles, and on the upper side of the base of the infraspiracular tubercles, is a little more distinct than in Stage IV., as in the latter stage the 2d and 3d thoracic dorsal and subdorsal tubercles are more orange than those on the abdomen, which are deep coral-red; but in some of Stage IV., the thoracic ones are coral-red.

The head is reddish chestnut, and is the same in hue as in Stages I. to IV. The prothoracic segment is edged with yellow, the pale yellowish lateral stripe as in Stages III. and IV. The spiracles are deep orange-red. The segments are now convex and almost angular, more so than in the other native forms of this group, unless we except *A. luna.*

One of this brood began to spin, and had completed the exterior of its cocoon by August 1.

The object of the purplish edging on the suranal plate and anal legs was impressed upon me while observing a large full-fed caterpillar resting by a short leafstalk, the leaf having been broken off so as to be a quarter of an inch long and curved. In color and shape it exactly resembled the purplish edgings of the suranal plate and legs, and thus added to the protective resemblance to a leaf and its stalk.

A fine large *T. polyphemus* was observed at Providence, September 27, on the chestnut. I was struck with the resemblance of the outline of the creature's back — the segments being angular so as to render the body serrate, each tooth-like form of the segment surmounted by a tubercle and long hair — to the serrated edge of the leaf, each of the teeth ending in a long hair. It is not improbable that the ancestors of Telea, Actias, and others with angular segments, may originally have fed on trees with such serrated leaves, and that later they adopted as their more usual food-plant such trees as the oak, in which the edges of the leaves are either smooth or simply lobed.

Recapitulation of the more Salient Ontogenetic Features.

A. Congenital Features.

1. The setæ (bristles) of Stage I. but little longer than the tubercles, and both truncate and distinctly bulbous at tip.
2. A slight but distinct differentiation in size and color of the dorsal tubercles, those of the 3d thoracic and 9th abdominal segments being of the same size, and larger than those on uromeres 1–7, and of a deeper yellow shade. (Stage I.)
3. The homologue of the "caudal horn" is distinctly double, and more deeply divided than in any other American genera of Attacinæ; each fork about as long as thick. (Stage I.)
4. Abdominal legs each with twenty-four crotchets (a larger number by 6 to 8 than in the other genera), Stage I.
5. Each abdominal segment (uromere) with a lateral pair of transverse black slashes in Stage I.
6. The two tubercles in Stage I. on the suranal plate slender, papilliform, and approximate.

B. Evolution of later Adaptational Characters.

1. The lateral pair of black transverse stripes on each uromere nearly or quite disappear in Stage II.
2. The segments more convex and angular in Stage III.

3. Appearance of a yellowish lateral oblique stripe connecting the lateral tubercles of the lower and upper row, in Stage III.
4. Appearance of the pale purplish edging of the suranal plate and anal legs, in Stage III.
5. Appearance in Stage IV. of the pearly spot on the outside of the dorsal tubercles.

The generic characters are mostly assumed in Stage III.

The Life History of Actias luna (Linn.).

The eggs were received from Mr. James Angus.

Egg. — Oval-cylindrical, somewhat flattened. The shell is thick and tough, dark brown externally, but in places the brown is worn off, leaving a dull, sordid chalky whitish surface; the inside of the shell slightly bluish gray. The surface of the shell is seen under a Tolles triplet to be rough and finely granulated, and under a half-inch objective, the surface is seen to be closely granulated, the pits between the granulations being often confluent; rarely the raised bosses appear to be polygonal. Length 2.1 mm., breadth 1.8 mm.

Larva, Stage I. — Length 6–8 mm. Some were observed hatching out between 11 and 1 o'clock P. M., June 15. Before entirely breaking out of the egg-shell the tubercles on the anterior segments become erect, and the hairs radiate from them, but behind along the 3d thoracic and abdominal segments the tubercles were seen to be soft, and flattened or appressed to the body, and adhering in flaccid bundles. In *P. cecropia*, on the other hand, all the tubercles and bristles are flabby for perhaps half an hour after the creature frees itself from the egg.

One was seen to emerge at 1.15 P. M., and by 1.25 P. M. all the tubercles had become filled out and erect, with stiff radiating bristles.* On hatching, the body is entirely green, except the bands on the head. Some larvæ on hatching are (*a*) entirely yellowish green, while the dorsal hairs are darkish, and the head is twice banded. Others (*b*) have *a very broad blackish lateral band*, enclosing one lateral row of greenish tubercles, the band ending on the 8th abdominal segment, and nearly meeting above. The prothoracic segment is dark on the hinder edge, and the 2d and 3d thoracic and 1st abdominal segments are entirely dark above.

* It is evident that before and at the point of hatching the setæ or bristles are filled with blood, which distends them. While thus distended, the fluid may ooze out of the ends, and thus they may be called glandular hairs. In those which are full and bulbous at the end, the fluid may be retained through Stage I., and in rare cases through the second or even the third stage.

The following description is drawn up from individuals which had been hatched for about a week (May 24–26), and were near the end of this stage. The body was larger, fuller, and less tapering posteriorly than at first. The head is small, about half as wide as the body, rounded, and at rest can be retracted within the prothoracic segment. There is *a transverse dark brown band in front just below the vertex, making two scallops*, and ending on the sides; on each side (below) of the front edge of the clypeus is a dark spot around the base of the antennæ, which sometimes sends *a short line inwards*, as in Mr. Bridgham's figure.

The body is thick, full, cylindrical, each segment, except the prothoracic and last two abdominal ones, with six thick, smooth conical tubercles, those on the sides above the spiracles smaller than those below, and about one half the size of the dorsal ones, and bearing fewer bristles than the others. Prothoracic segment with only four tubercles, the two dorsal ones low, flattened, and small, with about fourteen radiating bristles. The lateral tubercles are like those of the other segments; the rest of the dorsal tubercles are large, full, nearly touching at their base, and bearing about eight to ten bristles, which are one half to one third longer than the tubercles themselves; they radiate and are dark purplish, pale at base, those on the back darker than those arising from the lateral tubercles. *The 2d and 3d thoracic dorsal tubercles are slightly larger than the abdominal ones.* Each of the dorsal abdominal tubercles bears about six bristles. The body is delicate pea-green, nearly like the under side of the Carya leaf on which they feed. The tubercles, especially the dorsal ones, are tinged with faint straw or lemon yellow, while the lateral supraspiracular tubercles are greenish, scarcely tinged with yellow.

The bristles are longer in proportion to the tubercle than in the larva of *C. promethea;* most of them are three times and some four to five times as long as the tubercle. The bristles are sparingly and minutely barbed, tapering acutely, but they are clear, and perhaps glandular.

The median dorsal tubercle on the eighth uromere shows traces of its double origin, but they are not so marked as in *C. promethea* and *T. polyphemus*, but more so than in *Platysamia cecropia.* It is much broader than long at base, and on the tip bears five setæ on each side. The ninth uromere bears four tubercles of equal size, which are large and well developed, the lateral ones scarcely smaller than the dorsal ones. The suranal plate is broad and short, more so than in *T. polyphemus,* not tubercled, but bearing two tufts of bristles which are but

a little shorter than those arising from the lateral tubercles of the rest of the body.

The anal legs are large and squarish, as in the group generally; all the legs, both thoracic and abdominal, are pale green. The abdominal legs bear each twenty crotchets. The three tenant hairs of the thoracic feet are rather longer than usual. The spiracles are slightly chitinous, not colored.

The shape of the double dorsal tubercle on the 8th abdominal segment is shown at Figure 10, d'; *sd*, the subdorsal ones; a, a seta muc enlarged, which, unlike *T. polyphemus*, is finely and minutely barbed a', a'', ends of other setæ.

Stage II. — Moulted May 26, in the daytime. Length at fir 9 mm., afterwards 10 mm. In one larva all the tubercles are of th same yellowish hue; in the other, those of the 2d and 3d thorac segments are brownish at the tip, thus greatly contrasting with th others. In another larva the median dorsal tubercle on the eight uromere is also colored in the same way. The head in one is a green, not yet banded with brown; but in another the head is partl banded, i. e. in place of the two-scalloped band are two separate sho scallops.

The tubercles are now *higher than before*, and rough with slende conical warts which give origin to the setæ. The prothoracic tubercl

are now *longer than before*, and all four are deep amber-yellow at the end, the setæ being black; two out of the five spines of the 2d and 3d thoracic segments are dark brown at and near the ends, and give rise to black bristles, rendering them very conspicuous; they are a little larger and higher than those on the abdomen, and bear about twice as many bristles; eight in all, all of which are black, while on the yellow tipped tubercles of the abdominal segments there are about five bristles, one of them minute; two of the five are black, the others pale. The two lateral rows of tubercles are, as before, with pale bristles.

The median dorsal tubercle on the 8th uromere is not quite so dark as those on the 2d and 3d thoracic segments, and some of the latter are scarcely darker than the other abdominal ones. The spiracles are of the same pale color as before. The suranal plate still bears the two terminal tubercles, as before. The thoracic legs are now darker than before.

In this stage the larvæ sometimes assume a sphinx-like attitude.

Stage III. — Moulted June 1. (I am not sure that it was the same larva; one moulted May 31. Described three days after moulting.) Length 13 and finally 15 mm. The head is either banded as before, or all green, only the ocelli being black. The body is now thick, though differing very slightly from the preceding stage. The four prothoracic, the two dorsal 2d and 3d thoracic tubercles, and the single median dorsal tubercle on the 8th uromere are either deep crimson red at the end, or much paler, and in the largest one yellowish, the tips of these tubercles varying a good deal in color; *these tubercles are now nearly twice as long and thick as those on abdominal segments* 1 *to* 7 *and* 9. The tubercles of the two lateral rows are of the same size as before; those of the upper (supraspiracular) row are still green and small; those below, situated on the lateral ridge, are salmon-colored, and provided with black setæ, like those arising from the dorsal tubercles; near, and on the base of and between the tubercles are *white, delicate clavate hairs* (glandular?) which are not observable in the preceding stage; they are mostly confined to the abdominal, few, only one or two, on the thoracic region.

The thoracic legs are dark brown, pale at the tip; the abdominal legs except the anal pair, are green, with a transverse lilac line near the ends; beyond yellowish, while the plantæ are tinged with lilac. There is as yet no lilac tinge on the edge of the suranal plate.

Stage IV. — (Belonging to a later different brood; described July 24.) Length 23 mm. The head now pea-green, *not banded in front,* nearly as wide as the body; well rounded, and of the same shape as

in *T. polyphemus;* it is of a deeper pea-green than the body, which is in general, especially on the dorsal side, paler than in *T. polyphemus.* The labrum and jaws are pale. There is a chestnut-colored ocellar patch.

The segments are now *quite convex,* swollen under the base of the tubercles, the 2d and 3d thoracic segments being fuller and more angular than the uromeres; they are a little more so than in *T. polyphemus.*

The four dorsal tubercles of the 2d and 3d thoracic segments (two each) are larger than the abdominal ones, and *are tipped with dark carmine* at the end, and each, besides one or two short setæ, bears a long black slender hair, about as long as the body is thick; the corresponding hairs on the abdominal tubercles being about one third as long. There are four well developed prothoracic tubercles, the dorsal ones larger, more rounded and prominent than in *T. polyphemus,* and also bearing besides three or four small, short pale hairs, and a black very long one. The prothoracic tubercles are *deep rosy pink,* not coral-red. The lateral ones on the same segment are nearly twice as large as those behind in the same series, and all on the body are rosy pink or "crushed strawberry" color. The lateral infraspiracular ridge along the abdominal segments is distinctly lemon-yellow. The spiracles are faint reddish green, quite inconspicuous. The thoracic legs are reddish. The middle abdominal legs are green above, below is a narrow distinct black stripe, the end yellow, while the planta is livid flesh-color; the anal legs with an anterior oblique yellow band, and a black spot corresponding to the black stripe, with black hairs above, as on the middle legs. The suranal plate is faintly edged with yellow.

The larva in this stage differs from *T. polyphemus* of the same age in the *green* head, the distinct lateral yellow stripe below the spiracles, which are *green,* and not readily seen. The six dorsal thoracic tubercles are distinctly *larger and more prominent* than the abdominal ones, and they each bear a single very long slender black hair, besides one or two short ones; this is a good generic character, separating it at once from *T. polyphemus,* and the suranal plate is not edged with purple, but with faint yellow.

When fully fed,* its length is 65 mm. Maine, August 20. The head is green, of a different hue from the body, more like Paris-green. The body is large, heavy, plump, and thick, much as in *T. polyphemus,* and the tubercles are pinkish red, or crushed strawberry. The suranal

* Dyar states that there are but four stages.

plate is edged with yellow in front, but the surface is coarsely granulated, and in color dull amber; there is a similar long narrow patch on the side of the anal legs, bordered above with black and straw-yellow. The spiracles are green with the edge of the linear opening ochreous. The yellow lateral line is obscure. The body is still provided with white hairs, not arising from tubercles. The body is pea-green, dorsally slightly tinged with ruddy.

Recapitulation of the more Salient Ontogenetic Features.

A. Congenital Features.

1. Setæ tapering to a point, not bulbous, and finely barbed. Stage I. Most of them are three or four times as long as the tubercles.
2. Some larvæ in Stage I. with a very broad lateral dark band along the side of the body, some without it; no transverse stripes present, but the head in front is twice banded with dark brown.
3. The 2d and 3d dorsal thoracic tubercles differentiated in Stage I., being slightly larger than the abdominal ones.
4. On the suranal plate are two rudimentary tubercles, each bearing a tuft of bristles.
5. The dorsal median tubercle on uromere 8 does not show such marked traces of its double origin as Stage I. of *C. promethea*, or *T. polyphemus*, but it is more duplex than in *P. cecropia*.

B. Evolution of later Adaptational Characters.

1. Dorsal tubercles in Stage II. higher than before.
2. The lateral dark band disappears in Stage II.
3. In Stage III. the dorsal thoracic tubercles become nearly twice as long and thick as the abdominal ones.
4. The head is not banded in Stage IV.
5. The tubercles brightest (pink or dark carmine) and most conspicuous in the last stage.
6. A distinct infraspiracular yellow line in Stage IV., and the suranal plate and anal legs lined with yellow, and the surface of the suranal plate and sides of the anal legs amber.

VI.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XL. — AN INVESTIGATION OF THE EXCURSION OF THE DIAPHRAGM OF A TELEPHONE RECEIVER.

By Charles R. Cross and Arthur N. Mansfield.

Presented May 24, 1892.

In a paper published in these Proceedings,* by Messrs. C. R. Cross and H. E. Hayes, it was shown that with a magneto-telephone receiver the magnitude of the change in the strength of the magnet when a weak current is sent through the coil increases up to a certain limit as the strength of the magnet is increased, and then diminishes, the explanation of this diminution being found in the approach of the diaphragm toward saturation. The effect of varying the thickness of the diaphragm upon the magnitude of this change was also studied, and it was found that within the limits of the experiments the changed strength of the magnet due to the weak current is greater with thin than with thick diaphragms.

From these results it would naturally be inferred (1) that the amplitude of the vibration of the diaphragm of a telephone receiver would at first increase to a maximum, and then diminish, if the strength of the magnet were continually increased; and (2) that, within such range of thickness of diaphragm as would probably be most suitable in practice, a thin diaphragm is preferable to a thicker one.

The subject has also been studied by Mercadier,† by ascertaining the distance at which the beat of a metronome, when transmitted by telephone, just ceased to be audible under different conditions of the receiver as to the thickness of the diaphragm and strength of the polarizing magnet. In Mercadier's experiments the thickness of the diaphragms was varied through a far greater range than in those

* Vol. XXV. p. 233, 1890.

† Comptes Rendus, 1889, Vol. CVIII. pp. 735, 797; 1891, Vol. CXII. p. 96.

of Cross and Hayes, but their results are in substantial accordance with his for the same conditions of experiment, although the range of thickness in the diaphragms used by them was probably too small to produce the peculiar alternations of effect noticed by the former observer.

It seemed to the present writers desirable to verify these conclusions by direct observations upon the motion of the diaphragm itself, and the investigations detailed were undertaken with this end in view. We have thus far considered only the first of the two propositions just stated, leaving the second for future study. The experimental work was completed during the spring of 1891.

As it is very desirable not to have the free motion of the diaphragm interfered with in any way, we decided to make use of the stroboscopic method of observing its vibrations.

The telephone which we employed as a receiver had for its polarizing magnet a bar of Norway iron three fourths of an inch in diameter, and eight inches long, which was surrounded by a magnetizing coil consisting of 2750 turns of No. 18 (B. & S.) copper wire, whose resistance was approximately eight ohms. The line coil surrounding the end of the core was made of No. 36 (B. & S.) copper wire, and had a resistance of 99.5 ohms. The core was capable of being moved longitudinally by means of a screw, so that the distance of its end from the diaphragm could be adjusted. In all of our experiments the distance between the core and diaphragm was kept at $\frac{3}{64}$ of an inch. The strength of the magnet was varied by means of a resistance which altered the current passing through the magnetizing coil.

Since it seemed very doubtful whether the excursion of the diaphragm of the receiver when a current so feeble as that of a telephone was used would be sufficiently great to allow of satisfactory measurement, we decided to employ the alternating current from the secondary of a transformer through whose primary was passed the current from an ordinary alternating current dynamo making 128 complete alternations per second. By the introduction of a suitable wire resistance of variable amount into the secondary circuit, the current flowing in it could be reduced to a convenient strength, so that when the magneto-telephone was placed in a derived circuit running from extreme points on this wire the coils were traversed by a current comparable in magnitude with the ordinary telephone current. By operating with a current thus produced, and passing through the coils of the receiver, we hoped to be able to employ a current somewhat, but not very greatly, larger than the ordinary telephone current, so that we might

safely assume that the character of the phenomena observed with the former under the different conditions considered would be substantially the same as those occurring with the latter and weaker current.

The alternating current thus produced, which we will call the "line current," was measured by an electro-dynamometer included in the circuit, and placed between the resistance frame and the telephone coil. This electro-dynamometer was constructed especially for the purpose, and was calibrated in the ordinary manner, by passing a direct current of known and variable strength through its coils, making the usual reversals to eliminate the effect of the earth's magnetism.

The intermittent illumination needed for the purposes of our experiment was furnished by the sparks produced by a Helmholtz tuning-fork interrupter, making 128 complete vibrations per second. At each vibration, when the style broke contact with the mercury in the cup a bright spark was produced. The fork was so placed that this flash should illuminate the field of a microscope placed opposite, and which was focussed upon the end of a style carried by the diaphragm of the receiving telephone. The illumination given by the sparks, especially when concentrated by a lens, was abundantly sufficient to enable the observer to see the style as a silhouette against a bright field. The telephone was so placed that the vibration of the style was in a horizontal direction. When no current passed through the telephone the style was of course seen continuously, on account of the rapid recurrence of the sparks. If the rate of alternation of the alternating current employed is exactly 128 per second, thus coinciding in frequency with the sparks, then when this current is sent through the telephone coil, although the diaphragm will enter into corresponding vibration at the same rate, yet the style carried by it will still seem to be at rest when viewed by the microscope. But if the rates are not exactly the same, then of course the familiar stroboscopic effect will be produced, and the style will appear to be in a state of slow vibration, so that the amplitude of the vibration, if sufficient in amount, can readily be measured by means of a spider-line micrometer.

Using an objective having a focal length of half an inch, and an eye-piece of moderate power, and with a very weak magnet in the telephone, we found no difficulty in producing a perfectly measurable vibration with a current of only 5 milliamperes, while with a current of 29.5 milliamperes the excursion rose to fourteen thousandths of a millimeter.

On passing a current through the magnetizing coil alone, the diaphragm is of course immediately drawn towards the core by a certain

fixed amount, depending upon the magnitude of the current. Some measurements were made which show the amount of this deflection with increasing values of the magnetizing current. The results of these are given in Table I. The current is given in milliamperes, the deflection in thousandths of a millimeter.

TABLE I.

Current.	Deflection.
14	0.0
46	1.7
85	6.7
123	16.7
155	29.2
195	45.9
246	80.8
300	130.1
367	200.0
431	272.8
473	297.0
502	330.0
604	335.0

We did not carry the increase of current to a higher value, since the deflection of the diaphragm would have become so great as to carry the style out of the field of view.

A comparison of these results — best seen by plotting them as a curve, which we have not thought it necessary to reproduce here — shows that on increasing the magnetizing current the corresponding permanent deflection increases more and more rapidly in proportion up to a value of about $\frac{3}{10}$ of an ampere, after which the deflection is very closely proportional to the current.

In studying the effect of different degrees of magnetization of the core of the receiver upon the amplitude of the vibration of the diaphragm, our mode of procedure was to pass a known direct current through the magnetizing coil, and to vary the alternating line current through the receiving telephone coil, measuring this current by the electro-dynamometer. The extent of the excursion of the diaphragm for each different current was measured by the spider-line micrometer. The deflections given in the tables are each the mean of five readings. The process described was followed for various values of the magnetizing current, with the results shown in Table II. The figures in the first vertical column indicate the serial number of the measurements; those in the second, the strength of the magnetizing current in milliamperes, to which the strength of the magnet was found to be propor-

tional; the figures in the upper line headed L, the various values of the alternating line current in milliamperes; and the figures in the columns vertically beneath these last, the corresponding amplitude of vibration of the diaphragm in thousandths of a millimeter.

TABLE II.

No.	M	L			
		5.0	12.5	21.0	29.5
1	77	4	7	10	14
2	123	8	14	21	27
3	180	12	23	34	43
4	235	17	28	39	47
5	287	28	47	63	81
6	322	37	76	102	127
7	352	44	86	106	130
8	376	31	71	100	120
9	394	26	68	88	113
10	416	30	60	87	107
11	459	22	40	56	69
12	503	16	30	39	50
13	564	8	17	28	36
14	639	8	12	16	21

The results of a portion of the measurements are shown graphically by the curves in Figure 1. Only series 1, 3, 5, 6, 7, 11, 13, 14, are reproduced, as a greater number would have been likely to render the diagram confused. The abscissas are excursions of the diaphragm in thousandths of a millimeter; the ordinates, the line currents in milliamperes. The several curves are numbered to correspond with the serial numbers in the table.

It will be seen from these results, that, as the strength of the magnet of the telephone increases, the amplitude of the vibration likewise increases up to a certain limit, and then falls off. A comparison of them with a curve representing the magnetization of the magnet as

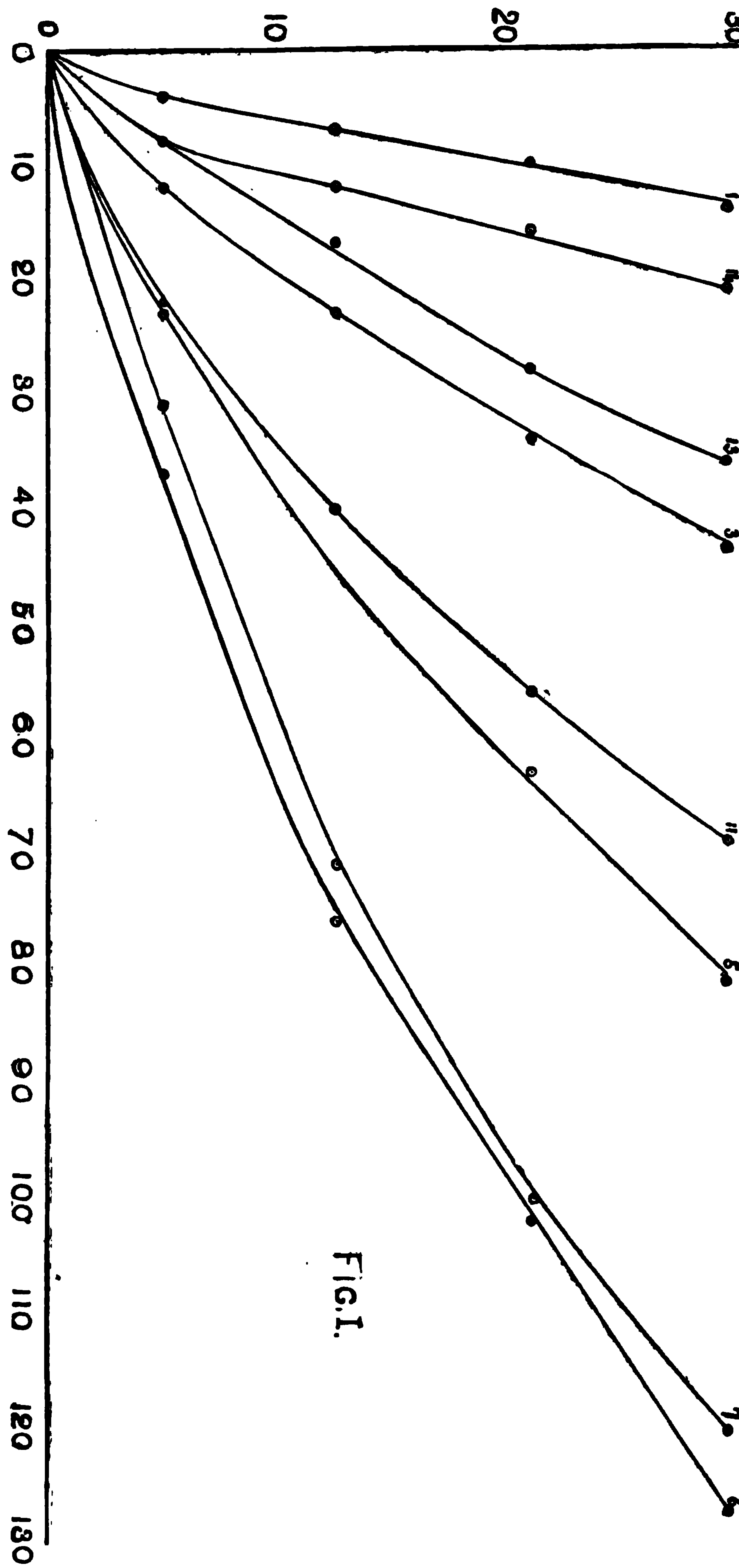


FIG. I.

determined by means of a ballistic galvanometer showed that the maximum motion of the diaphragm with a given value of the alternating line current is reached before the core reaches half-saturation.

An inspection of the curves also makes it plain that in general the amplitude of vibration of the diaphragm increases less rapidly than the current actuating the telephone.

In the experiments previously described the strength of the magnet was kept constant in each series, and the line current was varied. A series of measurements was also made in which the strength of the line current was kept constant, while the strength of the magnetizing current was varied, which shows very clearly the manner in which the amplitude of vibration changes with change in the strength of the magnet. Table III. gives the results obtained. The currents and amplitudes are given in terms of the same units as heretofore.

TABLE III.

Current.	Amplitude.
35	5.5
76	13.6
149	20.5
208	42.3
256	60.8
273	66.0
302	84.5
321	106.5
352	111.5
378	99.8
398	89.6
480	45.4
560	28.0
671	11.6
780	8.5
984	4.0
1142	3.0

Beyond the highest value given in the table, 1142 milliamperes, the excursion seemed to remain almost constant, and of too small a magnitude to be measured readily.

Figure 2 illustrates graphically the results obtained. The amplitudes of vibration are represented by the ordinates of this curve, while the abscissas represent, in terms of an arbitrary unit, the strength of the field at the diaphragm, as obtained from the previously constructed curve of magnetization already referred to.

The figures obtained in these measurements lead to precisely the same conclusion as those already discussed; showing that the amplitude of the vibration of the diaphragm produced by an alternating line current of a given strength increases up to a certain point, and then decreases to a very low value. The point of maximum amplitude is far below the saturation limit of the magnet. It is evident, then, that

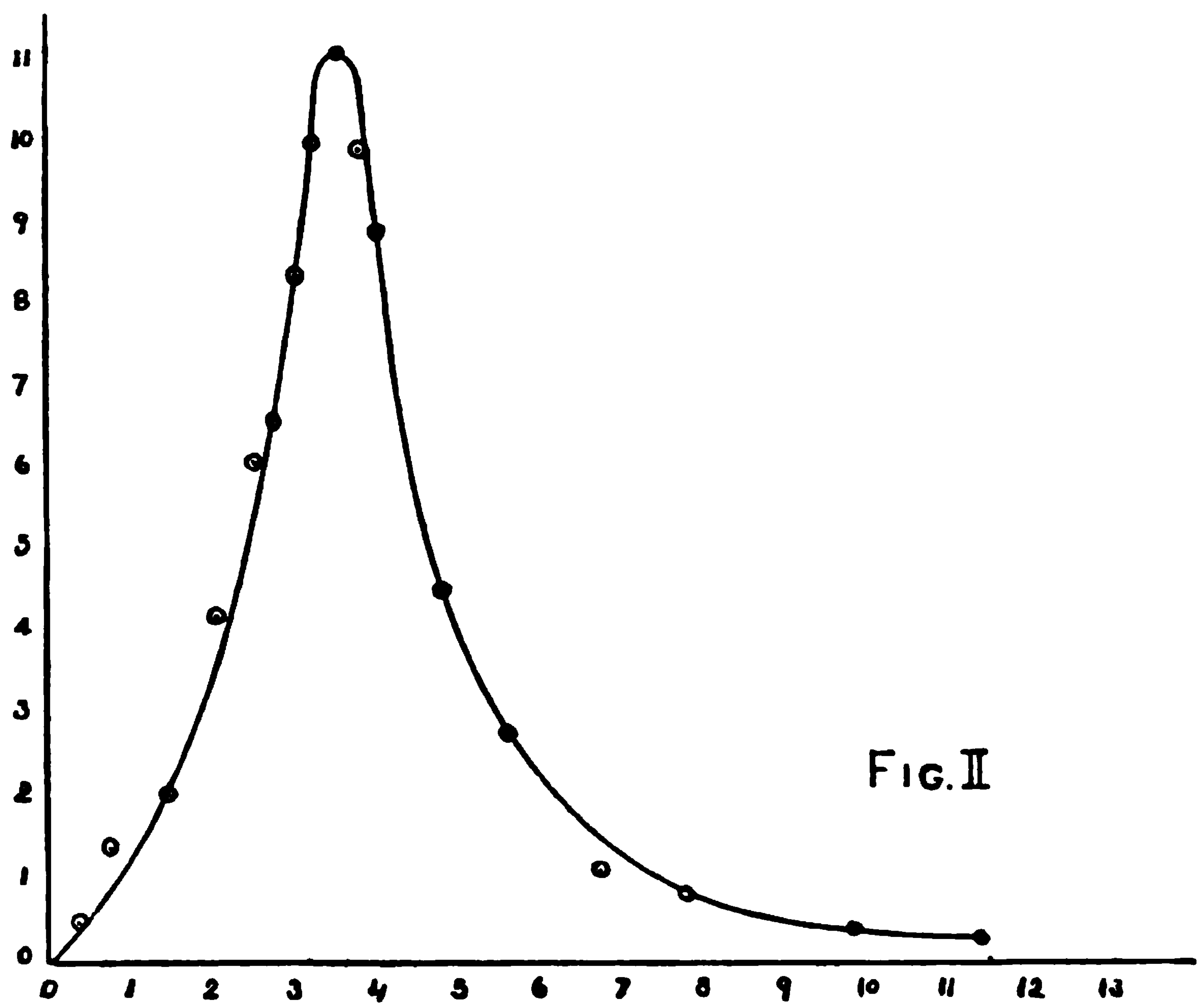


FIG. II

it is not desirable to use an excessively strong magnet with a magneto-telephone receiver, a result which agrees with the conclusions set forth in both of the papers cited at the beginning of the present article.

Our observations were not made with the direct intention of determining the absolute magnitude of the excursion of the telephone diaphragm, but they may throw some light upon the subject regarding which the figures given by different observers differ widely. Dr. C. J. Blake,* by inscribing the vibration on a plate of smoked glass, obtained a value of 0.02 mm., and by the use of a micrometer screw with galvanic contact a value of 0.0135 mm. Salet† employed an

* Jour. Soc. Tel. Eng., 1878, Vol. VII. p. 247.
† Comptes Rendus, 1882, Vol. XCV. p. 178.

optical method similar to that employed by Fizeau for measuring the expansion of solids, based upon the variation in position of Newton's rings when these were formed between a light piece of glass carried by the telephone disk and a fixed disk of the same material placed in front of it. The excursion as thus measured was from 0.0002 mm. to 0.0003 mm. Fröhlich* measured the excursion by means of a beam of light reflected from a mirror carried by the diaphragm, the beam being cast upon a screen and its motion measured when the receiver was operated. He gives 0.035 mm. as the value of the amplitude of the motion of the diaphragm. Franke† employed an optical method similar to that used by Salet, making the assumption that the amplitude of the vibration is proportional to the strength of the current, a supposition, however, which our own results, as given in the preceding pages, do not fully bear out; he concludes that the excursion of the diaphragm for a sound which is just audible is less than 1.2×10^{-6} mm.

Some of these differences are doubtless due to the different transmitters used. Blake employed a box magneto-transmitter, Salet a hand magneto, and Fröhlich a microphone. Also it is very possible that in some of the methods there is more or less interference with the free motion of the diaphragm. The following considerations may therefore be of interest, although they do not lead to absolutely conclusive results.

In all of our experiments, the line current had a value considerably in excess of even a strong telephone current. The weakest value of the line current employed was five milliamperes, while even two milliamperes is a large value for a telephone current produced by a powerful Hunning microphone transmitter. Hence the actual values of the excursions measured by us are much larger than those assumed by the diaphragm of the telephone receiver in practice. We have, however, endeavored to calculate this approximately from the data at hand. It is clear that, if we can obtain the equation of one of the curves in Figure 1, which corresponds to a strength of field of the magnitude employed in the ordinary telephone receiver, we may from this obtain the desired result by substituting in this equation the value of the telephone current. A study of the curves shows that they are all approximately parabolas with the equation $y^2 = mx^n$, n being greater than 2, but the values of m and n are different for the different curves. It was necessary therefore to determine by experiment the strength of

* La Lumière Electrique, 1887, Vol. XXV. p. 180.

† Elektrotechnische Zeitschrift, 1890, Vol. XI. p. 288.

the field actually employed in the magneto-receiver. This was done in the following manner. A magneto hand telephone was so placed that it produced a deflection of 45° in the needle of a delicate magnetometer. The telephone was then replaced by the magnet and magnetizing coil used in our experimental apparatus, and the current through the coil was varied until a deflection of 45° was produced in the needle. The current producing this effect was found to be 52 milliamperes. A like experiment being performed with a second telephone, the value of 62 milliamperes was obtained for the magnetizing current. The latter value was chosen, as it came nearest to a strength of current which we had actually used, viz. 77 milliamperes, the lowest magnetizing current that we had employed.

By the use of the logarithmic method the equation of this curve was found to be $y^2 = 0.305\ x^{3.26}$, in which y represents the current and x the corresponding amplitude of vibration. Substituting in this equation the value of 2 milliamperes for y, this being the value of a strong telephone current, we obtain the corresponding value of x, which is 2.2; that is, the excursion of the diaphragm of a telephone receiver with the strength of field corresponding to the curve would be 22 ten-thousandths of a millimeter. But the true excursion is probably somewhat less than this, since the strength of field for which the equation holds is somewhat greater than that employed in the telephone, and for a magnetization of this value the deflection would be larger with the stronger field.

It may also be inferred from the preceding results, that so far as sensitiveness is concerned it would be advantageous to employ a stronger magnet in the receiver than is at present used. With the modern microphone transmitter this is not necessary, and upon lines where there is much disturbance it would be harmful, as the proper procedure in such cases is to strengthen the transmitter as much as possible, in which case the receiver may be less sensitive. But if a less strong transmitter is used, as, for example, a magneto-telephone, and upon lines free from disturbance, increased sensitiveness in the receiver is very desirable.

Rogers Laboratory of Physics,
May, 1892.

VII.

CONTRIBUTIONS FROM THE GRAY HERBARIUM OF HARVARD UNIVERSITY, NEW SERIES.

III.* — ADDITIONS TO THE PHÆNOGAMIC FLORA OF MEXICO, DISCOVERED BY C. G. PRINGLE IN 1891–92.

BY B. L. ROBINSON AND H. E. SEATON.

Presented January 11, 1893.

THALICTRUM TOMENTELLUM. Polygamo-diœcious: stem striate, fistulous, finely and densely pubescent: leaves tripinnate: petioles 1–2 inches long, tomentulose as well as the rachis and petiolules: leaflets suborbicular, subcordate, finely pubescent above, paler and tomentulose below, shallowly 3-lobed; lobes rounded, entire or with 2–3 rounded teeth: inflorescence pyramidal, subnaked: sepals 4–5, ovate-elliptical, 2 lines long: stamens spreading; anthers with rather long setiform tips: fruiting heads nodding on the pedicels; carpels about 10, scarcely stipitate, lanate, rugose-reticulate, hispidulous, very acuminate, and tipped with a very long filiform finally deciduous style. — Low lands about Lake Patzcuaro, Michoacan, July, 1892 (n. 4143). Differing markedly in its fine soft pubescence from various allied species.

POLYGALA MICHOACANA. Perennial, glabrous: stems several, slender, erect, approximate, angulate, simple, or with a few long slender erect branches: leaves small, lance-linear, scarcely spreading, sessile, very sharply acuminate, 2–4 lines in length, not exceeding ½ line in breadth: spikes terminal, 1–2 inches long: bracts caducous, awl-shaped, very acute, purple, ¾ line long: flowers small, short-pedicelled, nodding, deflexed in fruit: sepals narrow, appearing very acuminate through the infolding of the margins, greenish white with purple midribs, the three smaller acute, the alæ pointed but obtuse,

* The two papers published by B. L. Robinson in these Proceedings, Vol. XXVI. pp. 164–176, and Vol. XXVII. pp. 165–185, are regarded as Nos. I and II of this series.

1½ lines long, but ½ line broad: petals white, not equalling the alæ: capsule orbicular, retuse, slightly margined. — Amongst pines, hills of Patzcuaro, Michoacan, August, 1892 (n. 4151). A species much resembling *P. scoparia*, HBK., but differing in its narrower and more pointed sepals, and in its orbicular not at all oblong fruit.

ABUTILON ATTENUATUM. Branches slender, terete, woody, stellate-pubescent: leaves lanceolate, attenuate, serrate, shallowly cordate, 2–2½ inches long, 10–12 lines broad, 3-nerved from the base, green and finely pubescent with simple hairs above, somewhat paler and soft pubescent with stellate hairs beneath: petioles 2–4 lines long: flowers in open terminal subsimple racemes: pedicels spreading, 7–9 lines in length: calyx lobes pubescent, ovate, acuminate, 3 lines long: corolla orange-yellow, once and a half as long as the calyx: capsule hirsute with spreading setaceous tips. — Slopes of mountains near Lake Chapala, Jalisco, November, 1892 (n. 4354).

PAVONIA MELANOMMATA. Two feet or more in height, finely glandular-pubescent: leaves ovate, acuminate, attenuate, crenate, soft pubescent above, velvety and cinereous beneath, 3–4 inches long, half as broad, the radical considerably smaller; petioles an inch long: pedicels ¾–1½ inches long: involucre of 5 linear bracts distinctly exceeding the calyx; the latter stellate-pubescent throughout: corolla externally pubescent, 1¼ inches in diameter, 3–4 times as long as the calyx, purplish white with an almost black glabrous centre; staminal column bearing near the base a number of short dark spatulate appendages (rudimentary stamens?): carpels glabrous, at maturity with sharp lateral angles, slightly keeled dorsally. — Volcanic hills, Monte Leon, Michoacan, November, 1892 (n. 4343). Possessing much the habit of *P. hirtiflora*, Benth., but having ovate crenate leaves, corolla smooth at the base within, and staminal appendages.

ASTRAGALUS TOLUCANUS. Root stout: stems several, slender, ascending, knotted below, minutely appressed-pubescent: stipules lanceolate, ciliate, acute, 2½–4 lines long: leaves 1½–2 inches long; leaflets 9–12 pairs, petiolulate, oblong, truncate or retuse, 2½–3½ lines long, glabrous above, appressed-pubescent below especially upon the midrib and near the margin: peduncles not exceeding the leaves: racemes dense, 1–2 or more inches in length: bracts oblanceolate to obovate, acute, pubescent, 2–3 lines long, persistent: pedicels a line in length: calyx light colored but covered with short black hairs; the teeth narrowly lanceolate, attenuate, 1¾ lines long, equalling the tube, densely black hairy: standard obovate, retuse, 5–6 lines long, it and alæ blue (in a dried state) and conspicuously striate with white: keel much

shorter and with a violet tip: pod oblong, smooth, 4 lines in length. — On drier ridges under pines, Nevado de Toluca, 12,000 ft., September, 1892 (n. 4238). Near *A. Mandoni*, Rusby ined., of Bolivia, represented by Bang's no. 1022, but differing in its more slender stems, smaller leaflets, and broader bracts.

STYLOSANTHES DISSITIFLORA. Much branched from near the base, 8–10 inches high, copiously beset with soft brownish setose hairs: sheath of the stipules 1½ lines long, equalling the subulate setiform appendages: free portion of the petiole 1–1½ lines long: leaflets linear lanceolate, sharply acuminate, somewhat narrowed but obtusish at the base, glabrous on both surfaces, strongly ciliate, 4–6 lines long, ¾–1¼ lines broad, veins prominent beneath: flowers scattered, pinkish: stipe of the calyx 1¾ lines long, divisions of the limb obtuse, ciliate: standard obovate-orbicular, retuse, 3 lines in length: alæ obovate with very slender auricles: fruit not seen. — Dry rocky soil, Rio Blanco near Guadalajara, September, 1891 (n. 5172).

COTYLEDON SUBRIGIDA. Glabrous, 1½–2 feet in height: leaves radical, sessile, ovate, acute, 3–4 inches long, two thirds as broad: stem and branches covered with a light bluish bloom: bracts of the stem 5–10 lines long, of the branches minute: inflorescence about a foot long, with about 8 spreading somewhat rigid racemosely 5–7-flowered branches: flowers large (¾ inch), approximate, borne on the upper side of the branches: pedicels a line or two in length: sepals lanceolate-acuminate, half the length of the petals; the latter lanceolate-acuminate, acutely keeled, somewhat gibbous at the base, red, internally tinged with yellow: stamens nearly equalling the corolla. — Ledges and cliffs, Tultenango Cañon, State of Mexico, October, 1892 (n. 4326). Near *C. gibbiflora*, Moç. & Sess., but with the branches of the inflorescence shorter and more rigid, leaves shorter, etc.

SEDUM PRINGLEI, Wats. var.? MINUS. An inch or less in height: inflorescence more dense: antheriferous stamens only 5. — Bare earth, summit of the Nevado de Toluca, September, 1892 (n. 4240). Perhaps distinct: also near Peyritsch's *S. napiferum*, but differing in stamens, etc.

CUPHEA (DIPLOPTYCHIA) AVIGERA. A slender annual a foot and a half high: stem slightly scabrous, the middle of each internode glutinous: leaves opposite, membranaceous, nearly sessile, narrowly lanceolate, 1½–2½ inches long, tapering almost from the subcordate base to the acuminate tip, roughened by minute hairs and somewhat adhesive: racemes axillary, alternate, loosely 3–5-flowered: bracts linear, much longer than the pedicels: bractlets none: calyx glandular-

hirsute, 4–5 lines in length, appearing horizontal, the ascending acutish spur being more than half as long as the proper tube, the latter narrowed upwards: the petals lilac, elliptical, subequal: the dorsal 2 lines, the four ventral 1½ lines long: stamens 11, included: ovules 6. — Moist banks, mountains near Lake Chapala, Jalisco, November, 1892 (n. 4349). A species well marked by the almost horizontal calyx, which in shape resembles the body of a bird.

CUPHEA (LEPTOCALYX) REIPUBLICÆ. Slender, decumbent, about 3 feet high, somewhat branched: stem slightly scabrous with minute transverse hairs attached in the middle and with a line of much longer hairs: leaves ovate, acuminate, hispid on both surfaces, paler beneath, 1–1½ inches long, two thirds as broad, abruptly narrowed at the base into a petiole 3–5 lines in length: pedicels interpetiolar, 3 lines long: calyx slender, nearly straight, almost an inch in length: the tube red with a white spot on the ventral surface at the summit, hispidulous, shortly and obtusely spurred: appendages linear oblong, setulose, green, considerably exceeding the lobes: petals deciduous, bright yellow, all small, the 2 dorsal 1¾ lines long, the 4 ventral about a line in length: stamens 9, unequally exserted: ovules about 12. — Rocky hills near Patzcuaro, Michoacan, October, 1892 (n. 4112). An attractive species, somewhat resembling the commonly cultivated *C. platycentra*, the calyx bearing the colors, red, white, and green, of the Mexican flag.

FUCHSIA PRINGLEI. Shrub, 2 feet high, with a brown shreddy bark: branches purple, pulverulent: leaves small, ovate-elliptic or lance-elliptic, obtuse, narrowed to a short petiole, somewhat undulate and revolute on the margins, very minutely pubescent above, considerably paler and nearly smooth beneath, about 4 lines long, half as broad: flowers 3 lines long, short peduncled, axillary, solitary: peduncles slender, 2 lines in length: calyx segments dark purple, oblong, apiculate, reflexed, two thirds as long as the free part of the tube: petals obovate, spreading, undulate, about equalling the segments of the calyx: stamens slightly exserted; style considerably so: fruit globose, 3–4 lines in diameter, black. — Mountains near Patzcuaro, Michoacan, November, 1891, in fruit (n. 5063); barranca near Guadalajara, Jalisco, September, 1891, also in fruit (n. 5002); and under pines, mountains near Patzcuaro, Michoacan, July, 1892 (n. 4140). This species differs from *F. minutiflora* and *F. mixta*, Hemsl., in its reflexed calyx segments, its undulate not serrulate leaves, and its relatively longer petals.

CYCLANTHERA PRINGLEI. Stem slender, nearly smooth, 5-ribbed:

leaves thin, ovate, undivided or more or less hastately 3-lobed, callous-denticulate, punctate on both surfaces, glabrous below, minutely pubescent on the nerves and somewhat scabrous above, 1–2 inches in length, acuminate and mucronate at the apex, deeply cordate at the base with a rounded open biglandular sinus: glands stipitate, minute, ¼–⅓ line in diameter, on pedicels of equal length: tendrils slender, simple: racemes 4–5 lines long: staminate flowers yellow, ⅔ line broad. rather single, annular, horizontal: fruit ½ inch long, 4 lines broad, very oblique and strongly curved, laterally compressed, acutely beaked, armed with a few short weak spines; the convex suture spirally revolute in dehiscence. — Rocky hills near Patzcuaro, Michoacan, October, 1892 (n. 4317). Near *C. biglandulifera*, Cogn. (ex char.), but with more simple tendrils and very much smaller glands.

PIQUERIA LAXIFLORA. A sparingly pubescent annual, 1½ feet high: stem weak, furrowed, branching: leaves thin, lanceolate, narrowed to an obtuse point, serrate, 3-nerved, 1½–2 inches long: petioles 3 lines in length: branches slender, terminating in loose panicles with flexuous filiform divisions: bracts minute, linear, 1–1½ lines long: pedicels filiform, spreading, 3–6 lines in length: heads 4-flowered: scales of the involucre 4 (2 narrower), thin, green, slightly fringed above and mucronate: achenes black, 5-angled, 1 line long, narrowed downward. — Cool slopes and ledges, Cañons of mountains near Lake Chapala, Jalisco, November, 1892 (n. 4333). Well characterized by its very diffuse inflorescence, which suggests *Valeriana sorbifolia* and allies.

PIQUERIA PRINGLEI. Rhizome horizontal, branching, several inches in length: stems subsimple, slender, erect, purplish, 1–1½ feet high, with a fine grayish pubescence: leaves broadly ovate, an inch in length, serrate, rather abrupt at the base, pubescent: petioles 3–4 lines long: inflorescence a rather dense irregular corymb: heads 2 lines long, 4-flowered: scales of the involucre 4, obovate, lacerate above and mucronate at the apex: corolla 1½ lines long: filaments pubescent: achenes glabrous, black, a line in length. — In pine woods, Nevado de Toluca, September, 1892 (n. 4285). Habit of *P. pilosa*, HBK., but differing in its well developed rhizome, in its leaves more abrupt at the base, and its pubescent filaments.

STEVIA LAXA. — Root of numerous strong fibres: stem erect from a slightly decumbent base, about 2 feet high, purplish, terete, puberulent, substriate, simple up to the lax finely glandular inflorescence: leaves rather numerous below, opposite, ovate, acutish, crenate-serrate, 1–1½ inches long, nearly smooth, paler beneath, contracted below into

petioles of almost equal length: heads rather few, very loosely disposed upon slender subdichotomous branches: scales of the involucre lance-linear, acuminate, a little over 2 lines in length, covered with fine dark glandular pubescence: corollas white, externally roughened and with a pubescent limb; tube exserted: achenes slightly roughened, 1¼ lines long; pappus lacerate coroniform; aristæ none. — Dry hills near Patzcuaro, Michoacan, November, 1891 (n. 5051). The same as Bourgeau's no. 3331, from Escamella, near Orizaba, October, 1865.

EUPATORIUM SALTIVARII, Schultz Bipontinus. Rootstock horizontal, branching: stems several, erect, purple, pubescent, glandular above, 1–2 feet high, throwing out several small weak branches near the base: leaves ovate, acute, coarsely serrate, abrupt at the base, pubescent on both surfaces, 1–1½ inches long, more than half as broad: petioles 3–4 lines in length: heads rather few, aggregated in small terminal corymbs, 4 lines high, about 50-flowered: involucral scales subequal in about two series, lanceolate, acute, ciliate, striate, the outer glandular: corolla tubes slender, as long as the ample throat: achenes slender, slightly curved, 1⅓ lines in length, hispidulous, callous-tipped at the base. This apparently good species of Schultz Bipontinus, founded upon Schaffner's no. 298 from the Val de Mexico, October, 1855, seems never to have been described. It has since been collected by Bourgeau in the same place (n. 818), and by Mr. Pringle in pine woods, Nevado de Toluca, State of Mexico, September, 1892 (n. 4286).

BRICKELLIA SQUARROSA. Stems subsimple, 2 feet or more in height, terete, covered with short dense pubescence, somewhat glandular roughened above: leaves opposite, oblong-lanceolate, obtusish, more or less acute at the base, crenate, 1½–2 inches in length, very rough and somewhat rugose above, prominently reticulated, hispid on the veins and black punctate on the surface below: petioles 4 lines long: heads 7 lines long, about 12-flowered, in a subsimple raceme: pedicels an inch long: the outer scales of the involucre shorter, herbaceous, squarrose, glandular; the inner thin, purplish-striate, acute: corolla lobes minutely callous-tipped: achenes pubescent: pappus appressed-barbellate. — Mountains near Patzcuaro, Michoacan, December, 1891 (n. 5054).

SABAZIA SUBNUDA. Root of many fibres from a short rootstock: stems slender, erect, pubescent, almost naked, bearing one to three large long-peduncled heads: radical leaves ovate-elliptical, obtuse, entire, triply nerved, narrowed to a short broad petiole, ciliate, glabrous

above, paler and subglabrous below, 1½–2 inches long; the cauline usually a single pair, reduced to short linear bracts: heads including rays 1½ inches broad: outer bracts of the involucre ovate, commonly purplish, obtusish, 4 lines in length, the inner somewhat longer, narrower and ciliolate: rays purplish white, oblong, conspicuously 3-toothed, exceeding half an inch in length, abruptly contracted below into a very slender tube: receptacle elongated: chaff filiform: achenes black, glabrous. — In pine forests, Nevado de Toluca, 12,000 ft., September, 1892 (n. 4226).

VERBESINA ONCOPHORA. Shrub: younger parts gray-tomentulose: leaves lance-elliptic, acuminate in each direction, thickish, 3–7 inches long, finely and rather regularly serrate, scabrous above, tomentose and pulverulent beneath with yellowish white hairs; petioles ⅓–½ inch long; a small fleshy folded finally deciduous appendage occurring on each side of the base: corymbs compound, many headed: heads 4 lines in diameter: scales of the involucre acute, not at all foliaceous: rays yellow, about 8, exserted 2–3 lines: disk flowers pubescent: achenes rather narrowly winged, 1½ lines long, hispidulous upon the faces. — Sierra de las Cruces, State of Mexico, October, 1892 (n. 4310); Bourgeau's 967, Forest of San Nicolas, near Mexico, 1865–66. Near *V. persicifolia*, DC., but differing in the greater pubescence and finer serration of the leaves, the presence of the peculiar excrescences on the stem at the base of the petioles, and in the pubescent corollas.

TRIDAX PALMERI, Gray, var. INDIVISA. Rough pubescent, almost hirsute: leaves ovate, rather irregularly dentate, scabrous, undivided. — Cañon ledges, mountains near Lake Chapala, Jalisco, November, 1892 (n. 4332). This plant corresponds except in its pubescence to Parry & Palmer's 489. But both of these specimens differ so conspicuously from the form of the species with divided leaves, represented by Parry & Palmer's 482½ and 490, and Schaffner's 236, that it seems best to characterize them as a variety. Parry & Palmer's 489 corresponds rather closely with this variety in its foliage, but is much less pubescent, and in this regard furnishes a transition to the smoother forms with undivided leaves, represented by the other type specimens (Parry & Palmer's 482½ and 496) and by Schaffner's 236.

SCHKUHRIA GLOMERATA. Roots fibrous: stem simple, erect, striate, glandular-hirsute, 1½ feet high: the lower leaves opposite, petiolate, minutely resinous-dotted, palmately 3-parted to the base; segments linear or linear-oblong, the middle one sometimes toothed, the lateral ones very deeply bifid: the upper leaves alternate, sessile, simplified: heads aggregated at the ends of the branches: pedicels

short: involucre commonly campanulate rather than turbinate, 2 lines long; bracts about 8, oblanceolate, pubescent, purplish, scarious-margined: rays none: disk flowers white, 10–12: achenes sharply 4-angled, very pubescent: pappus scales 8, suborbicular, narrowed and thickened toward the base. — Rio Hondo, State of Mexico, September, 1891 (n. 5006), and from the same locality, September, 1892 (n. 4289). Well characterized by its short-pedicelled, somewhat aggregated heads, and subcampanulate involucres.

SENECIO ALIENUS. Nearly smooth below, minutely glandular above: stem herbaceous, purplish, somewhat striate, with flexuous character suggestive of a climbing habit: leaves long-petioled, shallowly 3-lobed, broadly triangular in outline, or by the development of two obtuse angles near the base irregularly pentagonal, finely cuspidate-dentate, nearly smooth, light colored sometimes purplish beneath, 2½–4 inches in diameter, peltately attached near the subcordate base; lobes acute: inflorescence lax, irregularly racemose-paniculate: bracts filiform: the heads developing successively the highest first, 12–15-flowered: buds ovate: involucral bracts purplish, hispidulous and glandular, about 8 in number, linear lanceolate with incurved acute tips: corolla of Eusenecio: anthers sagittate: achenes glabrous, 10-ribbed. — Mountains near Patzcuaro, Michoacan, December, 1891 (n. 5056). In its peculiar inflorescence and successive development of the heads, as well as in its sagittate anthers, this species approaches the East Indian section Synotis.

SENECIO JALISCANA, Wats. (Proc. Am. Acad., XXVI. 143). Mr. Pringle's later specimens of this species add the following characters. Height 8–10 feet: lower leaves rather deeply cordate, shallowly lobed, 8 inches long, nearly as broad. — Cool wooded cañons, mountains near Lake Chapala, State of Mexico, November, 1892 (n. 4329).

CACALIA PLATYLEPIS. Root a cluster of strong fibres: stem herbaceous, woolly at the base, otherwise smooth, sulcate-striate: radical leaves long-petioled, ovate, cordate; limb coriaceous, smooth, strongly reticulated, pinnately divided, 10–12 inches long, two thirds as broad; segments irregularly 2–3-parted, the margins callous-denticulate: the cauline leaves much reduced, the upper consisting almost entirely of broad ovate sheathing petioles, toothed near the apex: heads corymbose, very large, 40–50-flowered, subtended by several laciniately toothed bracts: involucre broadly campanulate; the scales strongly imbricated in two series, ovate, thickened in the middle, acutish, the margins ciliolate, the tip bearing a tuft of hairs: corolla very slender, 6–7 lines long, the tube somewhat exceeding the limb: achenes

(immature) 1½–2 lines long, pubescent. — Collected by Dr. Edward Palmer on the Rio Blanco, Jalisco, October, 1886 (n. 689), and by Mr. Pringle on the plains of Guadalajara, November, 1888 (n. 1816). Both of these plants have been referred through some oversight to *C. raduliæfolia*, HBK., by Drs. Gray and Watson (Proc. Am. Acad., XXII. 433), and distributed under this name. They must, however, be very distinct from that species, which has, according to the description, numerous small 5-flowered heads. *C. platylepis* evidently stands close to *C. cervariæfolius*, DC., but is amply distinct in foliage and size of the heads.

CACALIA PELTIGERA. Roots several, short, thick and tuberous: stem herbaceous, about 3 feet high, terete, purple, nearly smooth: leaves mostly radical, long-petioled, centrally peltate, orbicular in outline, 8–12 inches in diameter, pubescent on both surfaces, especially upon the veins, deeply 9–11-parted with rounded sinuses; the lobes narrow, 2–3-parted; the divisions attenuate, sharply and irregularly toothed; the cauline leaves similar but smaller: heads small, 5–7-flowered, in a naked much branched corymb: bracts of the involucre about 5, oblong or oblanceolate, obtusish, 3 lines in length, with narrow scarious margins, and usually bearing at the tip a tuft of very short hairs: corolla 5 lines in length; the lobes exceeding the tube: achenes conspicuously striate-sulcate, nearly smooth, 2½ lines long. — First collected by Dr. Edward Palmer on the Rio Blanco, Jalisco, in 1886 (n. 171); then by Mr. Pringle on bluffs of a barranca near Guadalajara, September, 1891 (n. 5154). The former specimen was referred by Dr. Watson (Proc. Am. Acad., XXII. 432) to *C. Schaffneri*, Gray, from which, however, it differs essentially in its short thick roots, centrally peltate leaves with much more attenuate segments, and in its nearly smooth achenes.

CNICUS TOLUCANUS. Radical leaves lance-oblong, acute, about 25-lobed, green and strigose-pubescent above, much paler and somewhat arachnoid beneath, 7–10 inches long, 1½–2 inches broad; lobes ovate-oblong, acute, spinulose-dentate, gradually diminished downward: the cauline leaves much reduced, not decurrent: heads nodding, usually solitary at the ends of long slender nearly naked branches, 1½–2 inches in diameter: outer bracts of the involucre short, narrowly lanceolate, spinulose-dentate, with slender reflexed tips; the inner much longer, with dilated purple fimbriate unarmed tips: corollas purplish, 8 lines in length, glabrous: filaments puberulent; tails of the anthers lacerate-toothed: achenes compressed, black, smooth and shining, 2 lines in length. — Wooded cañons, Sierra de las Cruces, State of Mexico August, 1892 (n. 4308).

PEREZIA HEBECLADA, Gray (Pl. Wright. I. 127). This rare species has been rediscovered by Mr. Pringle, and his excellent specimens show the following additional characters. Leaves coriaceous, crowded, strongly reticulate, oblong, sagittate-cordate, abruptly pointed, 4 inches or more in length, nearly half as wide; the upper gradually diminishing in size, acuminate. — Pedrigal, Valley of Mexico, Federal District, December, 1892 (n. 4360).

PEREZIA VERNONIOIDES, Gray (Proc. Am. Acad., XXII. 433), founded upon Palmer's no. 745 from Jalisco, proves to be a form of *Vernonia serratuloides*, HBK.

LOBELIA PICTA. Glabrous, 6–8 inches in height: stems slender, decumbent, rooting from the lower joints, simple or with one or two branches from near the base, leafy, minutely angulate through the decurrent margins of the leaves: leaves linear, sessile, narrowed to an obtusish point, inconspicuously appressed-serrulate, 1-veined, thickish, 1 inch in length, ½ line in width; a few of the lowest leaves of a very different form, broadly spatulate, obtuse, 3–4 lines long, narrowed to a very slender petiole 6–8 lines in length: inflorescence spicate-racemose, raised on a naked peduncle an inch or more in length: bracts linear, 1–2 lines long, the lower equalling, the upper exceeding the pedicels: flowers nodding, ½ inch in length: calyx tube symmetrical, becoming in fruit almost hemispherical, exceeded by the linear acute serrulate teeth: corolla tube not equalling the calyx teeth, lobes lanceolate or ovate-lanceolate, acute, 3 lines in length, light blue or white, conspicuously pencilled with dark blue: filaments short, pubescent: anthers hispidulous, the two lower slightly smaller, tufted at the apex, the other three with minute setæ. — Cold springy meadows, Sierra de las Cruces, October, 1892 (n. 4305). A very attractive species with small but beautifully variegated flowers; to be distinguished from *L. Orizabæ*, Mart. & Gal., and *L. pauciflora*, HBK., by its very short corolla tube, by the hispidulous anthers, etc.; from *L. Irasuensis*, Plan. & Oerst., by the symmetrical calyx not acute at the base.

ARCTOSTAPHYLOS RUPESTRIS. A shrub 4–10 feet high with brown shreddy bark: leaves 4–5 inches long, coriaceous, oblong-elliptic, acute at both ends, finely serrate with cartilaginous teeth, when young erect, pubescent above, densely ferruginous-tomentose on the under surface, with age reflexed, glabrate above, and becoming less tomentose and tawny beneath, not however glabrate: racemes of the panicle rather loosely flowered, scarcely at all secund, covered with a fine grayish pubescence; bracts crimson, lanceolate, 3 lines long,

slightly surpassed by the straight spreading pedicels: corolla white, globose; filaments hairy at the base: fruit not seen. — Dry rocky hills near Patzcuaro, Michoacan, October, 1892 (n. 4318). Resembling *A. arguta*, Zucc., in the form and indentation of the leaves, but differing in their pubescence and in the inflorescence. Also near *A. attenuata*, Hemsl. (ex char.), but not glandular, and with acute by no means rounded leaves.

GENTIANA WRIGHTII, Gray. Mr. Pringle's no. 4237, from moist meadows, Nevado de Toluca, 11,000 ft., State of Mexico, September, 1892, is apparently a low and considerably branched form of this species, 4–6 inches in height; while no. 4196, from wet meadows, valley of Toluca, is another form nearer the type.

HALENIA CRASSIUSCULA. Biennial, glabrous, slightly fleshy, 2–4 inches in height: stem erect, very narrowly 4-winged, much branched: radical leaves oblanceolate, 3-nerved, petiolate, obtuse, including petioles an inch in length: cauline leaves 1–3 pairs, narrowly oblanceolate or oblong, obtuse, narrowed at the base: flowers including spur 6 lines long, densely aggregated at the ends of the stems and branches: calyx segments linear-oblong, obtuse, about half the length of the white corolla; spurs slender, spreading, and curved upwards; flowers after anthesis slightly nodding, not at all resupinate: capsules exserted, acute, 4 lines in length. — Bare alpine summits, Nevado de Toluca, 14,000 ft., September, 1892 (n. 4229).

HALENIA PRINGLEI. Glabrous: root biennial: stem single, simple or nearly so, slender, erect, a span high: radical leaves narrowly oblanceolate, 1-nerved, attenuate below to a slender petiole; the cauline 1–2 pairs, short, lance-linear: umbellate cymes usually 3; the lateral from near the middle of the stem, about 3-flowered, the terminal about 5-flowered: pedicels 3 lines in length: sepals oblong, acute, half the length of the corolla: corolla white, 4 lines long; spur slender, deflexed spreading and curved ascending, about equalling the corolla: capsule exserted, acutish. — Springy meadows, Sierra de las Cruces, State of Mexico, August, 1892 (n. 4209).

KRYNITZKIA LINIFOLIA, Gray. Mr. Pringle's no. 4241, from muddy hollows of prairies, Flor de Maria, September, 1892, closely approaches this species, and has been provisionally referred to it. It belongs to the imperfectly known group of South American Krynitzkias with procumbent subfleshy stems and linear opposite somewhat connate leaves.

RUSSELIA SUBCORIACEA. Glabrous: stems somewhat ligneous, branched, 4-angled: leaves opposite, very short petioled, ovate, acu-

minate, 2½ inches long, 1⅓–1¾ inches broad, subcoriaceous, slightly glossy above, a little paler and with prominent veins beneath, the edges crisp: flowers on short opposite branches; pedicels about 3 lines long, calyx teeth acuminate; corolla ¾ inch long, three times the length of the calyx, bright red; tube cylindrical, densely yellow bearded in the throat; lobes 4, the three ventral subequal, the dorsal broader emarginate; filaments bearded below; the rudiment one third to one half the length of the others: capsule ovate, 4 lines long, the acuminate valves at last bifid: seeds separated by hairs. — Tamasopo Cañon, San Luis Potosi, June, 1891 (n. 5086). This is an anomalous species, sharing almost equally the characters of Pentstemon and Russelia. However, its angled stem, short rudimentary stamen, cylindrical corolla tube, and the capillary structures between the seeds, show apparently a stronger affinity to the latter genus.

Castilleia pallida, Kunth. var.? angustata. A span high: leaves simple, linear: floral bracts lance-linear, acute: flowers pale yellow. — Grassy slopes near Patzcuaro, Michoacan, July, 1892 (n. 4117).

Pedicularis eburnata. Rhizome short, knotty: stem erect, hirsute-pubescent, terete, simple, 2–3 feet in height: leaves in outline lance-oblong, acuminate, 5–6 inches long; rachis pubescent; leaflets 16–22 pairs, ovate or lanceolate, acute, cleft into about 7 lobes, green and scarcely pubescent below; the segments margined with white ivory-like teeth; petioles of the radical leaves 2–3 inches long, pubescent; of the upper cauline leaves short or none: spike simple, more than a foot in length; bracts lance-linear, callous-denticulate with reflexed teeth, acuminate, the lowest surpassing and the others equalling the calyx: calyx 3–4 lines high, ovate, pubescent; teeth subequal, ciliate or slightly denticulate: galea narrow at the base, enlarged upwards, truncate at apex, considerably exceeding the lip, the latter 4 lines in length, with 3 orbicular crenate lobes; the middle one slightly smaller than the lateral: capsule smooth, ovate, 2-edged, shortly acuminate, 5 lines long. — Sierra Madre, 9,000 feet, Chihuahua, October, 1887 (n. 1556).

Dicliptera resupinata, Juss. var. orbicularis. Leaves large, ovate, 1½–2½ inches long: lateral pedicels very short: involucral bracts larger, thinner, and more deeply cordate than in the typical form, distinctly orbicular, retuse. — Barranca near Guadalajara, October, 1891 (n. 5169).

Salvia clinopodioides, HBK. Specimens corresponding accurately to Kunth's description and plate of this noteworthy species have

been found in sandy fields, hills of Patzcuaro, Michoacan, October, 1892 (n. 4258). They show that the plant is 1½ feet or more in height, and that the roots bear fusiform tubers an inch or two in length.

SPIRANTHES AURANTIACA, Benth. & Hook. var. ACUMINATA. Bracts narrower, acuminate, somewhat exceeding the flowers, the edges involute. Collected by Dr. Palmer in Jalisco, 1886, no. 581, and by Mr. Pringle on foothills of the Sierra Madre, Chihuahua, 1887 (n. 1509), and again on swells of low meadows, Valley of Toluca, September, 1892 (n. 4280).

DIOSCOREA MINIMA. Glabrous (♂ only seen): tuber globose, ⅓–⅔ inch in diameter: stem weak, flexuous, 1–3 inches high, about 2-leaved: leaves ovate, cordate, acuminate, about 9-nerved, 1 inch or less in length, on petioles 3–6 lines long: staminate spikes 2–4, slender, pedunculate or subsessile, less than an inch in length, rather densely flowered, not manifestly verticillate except below: bractlets linear, two thirds as long as the flowers: divisions of the perianth elliptical, obtuse, 1½ lines in length, white with a green midvein; stamens 3, a third shorter than the perianth. — Lava beds near Patzcuaro, Michoacan, July, 1892 (n. 4157). This species is nearly related to *D. multinervis*, Benth., but differs in the form of the leaves and in the length and color as well as somewhat in the arrangement of the flowers.

In the labels of Mr. Pringle's distribution of 1893 the following corrections are to be noted: —

4119, *Piqueria Pringlei*, Rob. & Sea.
4133, drop mark of interrogation.
4229, read *crassiuscula*, not *crassicula*.
4238, *Astragalus Tolucanus*, Rob. & Sea. n. sp.
4246, *Senecio procumbens*, HBK.
4296, add *ex char.*

VIII.

CONTRIBUTIONS FROM THE GRAY HERBARIUM OF HARVARD UNIVERSITY, NEW SERIES.

IV. NEW AND LITTLE KNOWN PLANTS COLLECTED ON MT. ORIZABA IN THE SUMMER OF 1891.

BY HENRY E. SEATON.

Presented by B. L. Robinson, January 11, 1893.

THE descriptions of new species and notes upon a few other plants of interest presented in this paper are based upon a collection made by the author on Mt. Orizaba in July and August, 1891. Mt. Orizaba in the State of Vera Cruz has been visited by a number of collectors, and is among the best known regions in Mexico. This is especially true of its lower slopes in the vicinity of the towns of Cordoba and Orizaba. These regions, where the writer's first collections were also made, are on the southeastern slope of the mountain at altitudes of 2,700 and 4,000 feet. Higher points were successively visited, until the station of Esperanza was reached, on the southern slope of the mountain and at an altitude of 8,000 feet. In this region seven of the new species here described were discovered. The ascent of the peak to an altitude of 14,000 feet was made on the western slope above the town of Chalchicomula. The remaining new species were found between 9,000 and 12,000 feet.

Drs. J. M. Coulter and J. N. Rose have been so obliging as to determine some of the Umbelliferæ, and their descriptions of two new species are herewith given. The notes upon the Grasses are kindly furnished by Prof. F. Lamson-Scribner. Warmest thanks are also due Dr. B. L. Robinson, for his ready assistance in many of the determinations.

RANUNCULUS GEOIDES, HBK. Pine woods, Mt. Orizaba, 11,000 ft., August (no. 179). This species has been somewhat confused with *R. Hookeri*, Schl., but is distinguished by its more simple habit, smaller and merely 3-lobed or parted radical leaves, and slightly narrower petals.

THELYPODIUM LONGIFOLIUM, Wats. Rich ravines, Mt. Orizaba, 10,000 ft., August (no. 250). The radical leaves are not present in the type of this species, and later specimens in the Gray Herbarium also lack them. The Mt. Orizaba specimens show them to be about an inch long, narrowly spatulate, obtuse, sparingly toothed at the apex, and very hispid with stellately branched hairs.

CERASTIUM ORITHALES, Schl. (Linnæa, XII. 209). Pine woods, Mt. Orizaba, 13,000 ft., August (no. 236). A very handsome species, well characterized by its simple stem and large flowers.

CERASTIUM VOLCANICUM, Schl. (Linnæa, XII. 208). Pine forests, Mt. Orizaba, 11,000 ft., August (no. 213). The specimens referred to this species have the petals but slightly cleft. The species is a prominent element of the herbaceous flora at an altitude of 11,000 feet.

ARENARIA SERPENS, HBK. In pine woods, Mt. Orizaba, 13,000 ft., August (no. 234). As defined by Rohrbach (Linnæa, XXXVII. 268), many forms are included under this species. The Mt. Orizaba specimens, which seem best placed here, are closely related to *A. Bourgæi*, Hemsl., but differ in the spatulate leaves and in the petals only equalling or little exceeding the sepals.

DRYMARIA FILIFORMIS. Glabrous throughout, 3–8 inches high: stems erect or spreading from a slender rootstock, much branched, filiform, somewhat rigid: leaves thickish, short-petioled, ovate to lanceolate, narrowed at the base, 2–2½ lines in length, reduced to ovate bracts above: stipules setaceous: flowers slender-pedicelled, disposed in a diffuse cyme: sepals ovate, obtuse, herbaceous, scarious-margined, with a dark tip or midnerve, somewhat carinate, a line long: petals deeply cleft, shorter than the sepals: capsule globose, shortly stipitate, many seeded.— Barren slopes, Mt. Orizaba, 9,000 ft., August (no. 267). Resembling *D. anomala*, Wats., in habit, foliage, and somewhat in the inflorescence, but differing in the slender rootstocks, glabrous obtuse sepals, and much longer-pedicelled flowers at the nodes of the branches.

ASTRAGALUS (MOLLISSIMI) ORIZABÆ. Stem decumbent, branched, clothed with a short white tomentum, a foot or less high: leaves including petiole 4–6 inches long; leaflets 14–17 pairs, petiolulate, oblong-lanceolate, obtuse or acutish, somewhat cuneate at the base, 5–8 lines in length, white sericeous-pubescent: stipules narrowly deltoid, acuminate, 2–2½ lines long: peduncles shorter than the leaves: racemes oblong, 1½–2½ inches in length: bracts linear-lanceolate, 1¾ lines long, exceeding the pedicels: calyx sericeous-pubescent, 3–4 lines in length, the linear acuminate teeth three fourths as long as the

oblong-campanulate tube: corolla yellow, the keel tipped with violet; standard obovate, 7–9 lines long, much exceeding the keel: pods coriaceous, brown, broadly ovate or globose, very obtuse or abruptly pointed, 6–7 lines long, somewhat sulcate on both sutures, pubescent with short white woolly hairs. — Ledges and cliffs, Mt. Orizaba, 9,000 ft., August (no. 262). This species is closely related to *A. Humboldtii*, Gray, but differs essentially in its obtuse or abruptly pointed subglobose tomentulose pods.

Desmodium (Heteroloma) subsessile. Stem herbaceous, trailing, branched, somewhat hispid: stipules lanceolate, acuminate, ciliate, 3 lines long: petioles 1–1½ lines in length: lateral leaflets elliptic, occasionally with a couple of rounded lateral lobes, the terminal leaflets broadly ovate, rounded or retuse at the apex, rounded at the base, thinly appressed-pubescent on both surfaces, ciliate: racemes terminal and axillary, long-peduncled: bracts ovate, acuminate, ciliate, soon deciduous: pedicels in pairs, distant, spreading, 6–7 lines long: flowers about 4 lines in length: pods (immature) 5–6-jointed, the margins nearly equally notched; joints orbicular, 1½ lines long, finely uncinate-pubescent. — Wooded hills near Esperanza, 8,000 ft., August (no. 325). Near *D. Mexicanum*, Wats., but distinguished by its foliage.

Phaseolus (Drepanospron) Esperanzæ. Stem procumbent, stout, furrowed, hispidulous with reversed hairs, 3 feet or more in length: leaflets broadly ovate-triangular, 1¾–2 inches long, three fourths as broad, obtusely and hastately 3-lobed, the lateral leaflets often entire or with one large rounded lobe, strigulose above, pubescent on the nerves below; the lateral lobes rounded, the terminal triangular, obtuse, mucronate: racemes loosely many-flowered: bracts persistent, ovate-lanceolate, acute, ciliate, 2 lines long, shorter than the pedicels: calyx pubescent, 1¾ lines in length: corolla greenish yellow, tinged with purple, 6 lines long: pods (immature) villous, slightly curved, ¾ inch long, 2 lines broad. — Wooded hills near Esperanza, 8,000 ft., August (no. 371). Closely related to *P. pedicellatus*, Benth. (ex char.), but differing in the shorter pedicels and pubescent stems and leaves; also near *P. leptostachyus*, Benth. (ex char.), which has rhombic-ovate leaflets.

Eryngium (Parallelinervia) Seatoni, Coulter & Rose, n. sp. Stem erect, stout, 3–4 feet high: leaves linear, parallel-nerved; radical leaves 12–15 inches long, 4–5 lines wide, the margin toothed with paired spines, one much longer and about equal to the breadth of leaf; stem leaves all alternate, with marginal spines often in threes and

fours, clasping at base: heads few, terminal and axillary, shortly pedunculate, oblong, 10 lines long; involucre of 14 or 15 bracts, oblong-linear, sharp pungent, 2 inches or more long, with 3 or 4 pairs of spines or the inner ones sometimes entire; bractlets blue, pungent, a little longer than the flowers. — In pine woods, Mt. Orizaba, 12,000 ft., August (no. 197). Near *E. protæflorum*, but with more scattered stem leaves, narrower radical leaves, fewer bracts, and bearing several heads. Galeotti's no. 2763, which was found on this mountain at exactly this altitude and referred to *E. protæflorum*, is in all probability the above plant.

ARRACACIA NUDICAULIS, Coulter & Rose, n. sp. Acaulescent, glabrous, with slender peduncle, 3–12 inches high: leaves 4–7, pinnate; segments linear, entire or the lower ones 3–7-toothed or pinnatifid, the ultimate segment appendiculate: umbel somewhat unequal, 6–12-rayed; rays 1–2 inches long; pedicels 2–3 lines long: flowers white: fruit ovate, flattened laterally, 1½ lines long: stylopodium conical, becoming inflexed; styles slender, thickened at tip. — Pine woods, Mt. Orizaba, 12,000 ft., August (no. 199).

GNAPHALIUM POPOCATEPECIANUM, Sch. Bip. Sandy plains, Mt. Orizaba, 14,000 ft., August (no. 242). This plant is the same as Schaffner's no. 50, Coulter's 451*, and one collected by Galeotti. Also very near *G. Liebmanni*, Sch. Bip. (ex char.).

IOSTEPHANE HETEROPHYLLA, Benth. Specimens of this plant collected in moist woods near Esperanza, 8,000 ft., August (no. 366), show the stem to be foliaceous to the summit and the rays dark red.

VIGUIERA PEDUNCULATA. Stem erect, about 3 feet high, smoothish, branched only at the summit: leaves opposite, distant, petiolate, coriaceous, undulate-serrulate, 3-nerved from the base, somewhat scabrous above, minutely pubescent on the nerves below; lower leaves deltoid, acute, about 3 inches long, 1½–2 inches broad; the upper ovate, acute, cuneate at the base, 1¼–2¼ inches in length: peduncles 1–3 at the ends of the branches, 5–11 inches long: heads solitary, 1¼–1¾ inches in diameter: involucre 4 lines high; the bracts lance-linear, apiculate, pubescent: rays 12–15, 6–8 lines long, oblong-elliptic, minutely emarginate: bracts of the convex or subconical receptacle entire, cuspidate, about equalling the disk corollas: achenes oblong, finely pubescent, 1½ lines in length: pappus awns chaffy-dilated at the base, nearly as long as the achene; the intermediate paleæ laciniate. — Wooded hills near Esperanza, 8,000 ft., August (no. 368). A species well characterized by its long-pedunculate heads.

ENCELIA STRICTA. Roots fibrous: stem simple, herbaceous, striate, hispidulous, about 2 feet high: leaves opposite below, alternate above, sessile, erect, somewhat appressed to the stem, oblong-ovate, 1–2½ inches long, truncate, rounded or subcordate at the base, acute, appressed pubescent and somewhat scabrous above, finely and rather soft pubescent with whitish hairs beneath, irregularly callous-serrate: heads few, pedunculate, ¾–1½ inches broad: bracts of the involucre 2–3 lines high, ovate, acute, densely appressed-pubescent: rays 8–12, oblong-elliptic, entire or minutely 2–3 dentate, 5–7 lines long, golden yellow: achenes oblong-spatulate, 1–1½ lines in length, slightly emarginate: pappus of two delicate awns, half as long as the achene. — Grassy hills near Esperanza, 8,000 ft., August (no. 339). Near *E. hispida*, Hemsl. (ex char.).

CALEA MULTIRADIATA. Herbaceous, erect or decumbent: stem somewhat branched, hispidulous, 1–2½ feet high: leaves opposite, sessile or very short petioled, lanceolate to broadly ovate, rounded or subcordate at the base, acute, serrate with a few callous-tipped teeth, rough pubescent on both surfaces, the veins prominent beneath: heads long-peduncled, 1–3 at the ends of the branches: involucre 3–4 lines high; its bracts green, ovate, obtuse, glabrous, ciliate, striate, the outer ones a little shorter and thickened at the tip: rays 15–25, oblong-spatulate, 3–5 lines in length, 2–3-dentate, purplish white, striate: bracts of the receptacle slender, acuminate, shorter than the flowers: achenes black, pubescent, less than a line long, angled, narrowed at the base: pappus paleæ about 20, slender, setaceous, minutely dentate, persistent, considerably longer than the achenes and equalling the corollas. — Wooded slopes, Mt. Orizaba, 10,000 ft., August (no. 167). This species is related to *C. elegans*, DC., but amply distinguished by its pubescence, more equal involucral bracts, and the number, size, and shape of the rays; also near *C. sabazioides*, Hemsl. (ex char.), but differing in the leaves and involucre.

TAGETES LINIFOLIA. Glabrous, about a foot high: stems several from a short rootstock, erect or decumbent, simple or with a few branches from the woody base: leaves opposite, sometimes alternate above, pinnate: leaflets 3–5 pairs, mostly opposite, narrowly linear with attenuate base, very acute or shortly setaceous, entire or serrate at the apex: lateral leaflets 3–6 lines, the terminal about an inch in length: peduncles single, terminating the stems or branches, cylindrical, 3–5 inches long: heads solitary: involucre oblong, narrowed at the base, ½ inch high, somewhat angled, 5-toothed: rays 5, conspicuously obcordate, light yellow, 6–8 lines in length: disk flowers 25–40,

exceeding the involucre: achenes 3–3½ lines long, linear, angled, minutely appressed-pubescent: pappus of the disk achenes of 2 paleaceous awns equalling the achenes, and 3 much shorter oblong slightly fimbriate paleæ; of the ray short paleaceous. — Rocky hills near Esperanza, 8,000 ft., August (no. 355). Resembling *T. pedunculata*, Lag., and *T. tenuifolia*, Cav., in the characters of the flowers, but with narrower leaflets and more simple stems terminated by single peduncles.

Senecio Orizabensis, Sch. Bip. Specimens collected on sandy plains, Mt. Orizaba, 13,500 ft., August (no. 219), accord in every way with the description of this species (Hemsl. Biol. Cent. Am. Bot., II. 244), except in having runcinate radical leaves.

Euphorbia ramosa. Suffrutescent, 2–5 inches high: stems decumbent or erect, slender, much branched, pubescent with spreading hairs: leaves short-petioled, oblique at the base, ovate or suborbicular, acutish, crenulate or very entire, glabrous above, sparsely hairy beneath, 2–3 lines long: stipules minute, triangular, lacerate: involucres solitary or somewhat corymbose at the ends of the branches, short-pedicelled, campanulate, glabrous, ½ line long: glands purple: appendages small, white, entire: styles very short, deeply bifid: capsules glabrous, the valves obtusely angled: seeds ovate, 4-angled, irregularly and transversely rugose. — Rocky slopes, Mt. Orizaba, 10,000 ft., August (no. 495). Coulter's no. 1447 from Real del Monte also represents small specimens of this species. It is cited by Hemsley (Biol. Cent. Am. Bot., III. 90) as *E. adenoptera*, Bertol., but it is very distinct from that species, which has unequal involucral appendages and hirsute capsules. The specimens in the Gray Herbarium were unnamed, but the following characters had been noted upon the sheet by Dr. Engelmann: " Stem and lower side of oblique ovate or orbicular crenulate or entire leaves hairy: stipe 3-angular, ciliate: involucre with small white and wide appendages: styles divided to the middle: capsule obtuse-angled: seeds sharp-angled, dark, cross-grooved, 0.5 line." The specimens were mounted on the same sheet with *E. pilosula*, Engel., and the two are nearly related in their pubescence and flower and fruit characters, but *E. pilosula* is a much smaller plant with distinctly serrate leaves. The specimens from Mt. Orizaba, varying from 2 to 5 inches in height, differ only from Dr. Coulter's plant in being apparently more erect, and they somewhat resemble in habit *E. Fendleri*, Torr. & Gray, and smaller forms of *E. villifera*, Scheele.

Arundinella Deppeana, Nees in Bonplandia, III. 84; Steud. Syn. Gram. 115; Fourn. Mex. Pl. Enum., Gram. 54. — Hills near

the town of Orizaba, 4,000 ft., August (no. 290). Equals no. 1552 of Wright's Cuban Coll., and Pringle's nos. 2615 and 3133. Not *A. Brasiliensis*, Raddi, as figured by Trinius (Icon. 266). Hemsley (Biol. Cent. Amer. Bot., III. 252) unites *A. aleutica*, Rupr., and *A. latifolia* and *A. scoparia*, Fourn., with *A. Deppeana*, Nees.

ORYZOPSIS PUBIFLORA (Trin.), Scribner. (Ex descrip. *Urachne pubiflora*, Trin. & Rupr. Stipac. 21; *Nasella pubiflora*, Desv. Flor. Chil. 264.) Culms slender, 2 feet high, with an open few-flowered panicle: spikelets 2–2½ lines long; empty glumes lanceolate, subequal, 3-nerved, with abruptly acuminate hyaline tips; flowering glume, including the short conical and curved callus, 1¼ lines long, obliquely truncate at the broad apex, and pilose all over with appressed hairs: hairs on the callus short and dense: awn about 6 lines long, twice geniculate, minutely ciliate below, scabrous above, readily falling off: anthers bearded at apex. — Hills near Esperanza, 8,000 ft., August (no. 319). Equals no. 2018 of Bang's 1891 collection.

MUHLENBERGIA SEATONI, Scribner, n. sp. Panicle diffuse, the upper branches widely spreading; flowering glume four times as long as the obtuse empty glumes, bifid at apex, the divisions setiform; awn about three times the length of the flowering glume.

Perennial: culms smooth, slender, branching near the base, 8–12 inches high (including the panicle): leaves linear-filiform, 2–3 inches long; ligule prominent, hyaline: panicle nearly one half the length of the culm, the lower branches ascending, partly included in the upper leaf-sheath; pedicels long and capillary, much exceeding the spikelets: spikelets about 2 lines long; empty glumes small (⅓ line), rounded, obtuse, the second a little longer and broader than the first: callus conspicuous, hairy on the anterior side: palea broad, nearly equalling its glume in length: awn about 6 lines long. — Hills near Esperanza, 8,000 ft., August (no. 320). It is allied to *M. capillaris*, Trin., but quite distinct.

AGROSTIS VERTICILLATA, Vill. Delf. 74; Trin. Unif. 195; Trin. Icon. 36. Kunth (Enum. Pl. I. 219) refers this to *A. stolonifera*, L., but there is some confusion in regard to the Linnæan plant. Munro, in his "Catalogue of the Grasses in the Herbarium of Linnæus," says, under *A. stolonifera*, that "the Herbarium contains one of the forms of *A. vulgaris* which is called *stolonifera*, the Florin grass; another marked *stolonifera* by Linnæus is *A. verticillata*, Vill." — Mt. Orizaba, 10,000 ft., August (no. 192).

CALAMAGROSTIS SCHIEDEANA, Steud. Gram. 193. (Ex descrip. *Deyeuxia Schiedeana*, Rupr. ex Fourn. Mex. Pl. Enum., Gram. 105.)

— Culms 12 to 18 inches high, with long involute erect leaves, and a short lax panicle: spikelets sometimes 2-, very rarely 3-flowered, 3–3½ lines long; empty glumes lanceolate, acuminate; flowering glume broadly lanceolate, pilose all over, laciniate at apex: awn from near the middle on the back, 2–3 lines long, bent and a little twisted below; rudiment nearly half as long as the floret, pilose: hairs on callus short, one fifth as long as the glume. — Mt. Orizaba, 14,000 ft., August (no. 227 a).

TRISETUM ELONGATUM, Kunth, Gram. I. 101, Enum. Pl. I. 296. This appears to be the same as *T. interruptum*, Buckley, and is probably the *T. interruptum* of Fournier. — Mt. Orizaba, 12,000 ft., August (no. 191).

TRIODIA AVENACEA, HBK. Nov. Gen. 156, t. 48. (*Uralepis avenacea*, Kth.; Fourn. Mex. Pl. Enum., Gram. 110.) — Mt. Orizaba, 9,000 ft., August (no. 248). Equals Pringle's no. 3930 and Schaffner's 1008. Spikelets 6–8-flowered, about 4 lines long; empty glumes unequal, the larger second one 2½ lines long; first flowering glume 2 lines long, oblong, deeply notched at apex, awned between the divisions: awn about 1 line long.

ERAGROSTIS LUGENS, Nees. S. Wats. in Proc. Am. Acad. XVIII. 182. — Hill near Esperanza, 8,000 ft., August (no. 318). Equals Pringle's no. 472. I have this species from Louisiana, collected in cultivated fields at Lafayette by A. B. Langlois, Sept. 25, 1885.

FESTUCA TOLUCENSIS, HBK. Nov. Gen. I. 153? — Mt. Orizaba, 12,000 ft., August (no. 193). Equals Pringle's no. 5201. This, and also no. 228 of same collection, appear to me to be only varieties of *Festuca ovina*, L. The no. 228 may be Fournier's *F. æquipetala.*

FESTUCA RUBRA, L., var. PAUCIFLORA, Scribner, n. var. Spikelets 3-flowered: upper flower imperfect: empty glumes unequal; the lower shorter and narrower: flowering glumes lanceolate, acuminate, submucronately pointed, scabrous on the back. — Mt. Orizaba, 13,000 ft., August (no. 227 b). This may be *F. Willdenoviana*, Schult., but it appears to be only a variety of *F. rubra*, L.

BROMUS HOOKERI, Fourn., var. SCHLECHTENDALII, Fourn. Mex. Pl. Enum., Gram. 127. — Mt. Orizaba, 10,000 ft., August (no. 189). Equals Pringle's no. 1173. This has been referred to *B. carinatus*, Hook., but upon what authority I do not know. Hooker's species does not appear to be clearly known.

IX.

CONTRIBUTIONS FROM THE GRAY HERBARIUM OF HARVARD UNIVERSITY, NEW SERIES.

V.—THE NORTH AMERICAN SILENEÆ AND POLYCARPEÆ.

By B. L. Robinson.

Presented April 12, 1893.

The following study of the *Sileneæ* and *Polycarpeæ* is preliminary to treatment of these tribes of the *Caryophyllaceæ* in the "Synoptical Flora of North America." The object of the present publication is chiefly to secure aid through criticisms, and to call attention to such species, especially in the genera *Silene* and *Lychnis* as are still imperfectly known, so that if possible more complete material of them may be secured before final revision for the first volume of the Synoptical Flora. Specimens of these groups, especially puzzling forms from the West and Northwest, together with notes concerning any points not properly covered by the following descriptions, will be gratefully received by the author, who here cordially acknowledges the valuable assistance already rendered him in his work by the late Dr. George Vasey and Dr. J. N. Rose, of the Department of Agriculture; Prof. N. L. Britton of Columbia College; Mr. and Mrs. T. S. Brandegee and Miss Alice Eastwood, of the California Academy of Sciences; Prof. John Macoun, of the Canadian Geological Survey; Mr. John H. Redfield, of the Philadelphia Academy of Natural Sciences; Mr. John Donnell Smith, and others, whose names are mentioned in the text. In the enumeration of synonyms and the citation of literature Dr. Sereno Watson's "Bibliographical Index" has been a most useful guide; so far as possible, however, all references to literature as well as points of synonymy, from whatever source, have been subjected to careful verification.

CARYOPHYLLACEÆ, Tribe I. SILENEÆ. Sepals united into a 4–5-toothed or lobed tube or cup. Petals unguiculate and often scale-bearing at the junction of the blade and claw, borne together with

lanceolate, sessile: flowers very large, an inch or more in diameter, loosely cymose; the central ones commonly nodding or reflexed after anthesis: calyx clavate or oblong, 8 lines in length, becoming obovate in fruit: petals crimson; the blade broadly lanceolate, 2- (rarely 4-) toothed at the apex. — Spec. 419 in part, not Willd.; Bot. Mag. t. 3342; Torr. & Gray, Fl. i. 192; Chapm. Fl. 51. *S. Catesbæi*, Walt. Car. 142. *S. coccinea*, Moench, Meth. Suppl. 306. — Common in open woods, on rocky hills, W. New York, S. W. Ontario (acc. to *Macoun*) to Minnesota (acc. to *Upham*), southward to Georgia and Arkansas.

S. rotundifolia, Nutt. (Round-leaved Catchfly.) Viscid-pubescent: stems weak, decumbent, branched: leaves rather large, varying from broadly lanceolate to subrotund, rather abruptly pointed; the lower ones contracted at the base to winged petioles: flowers large, showy, scattered or in loose cymes: calyx tubular, 10–13 lines in length, abrupt at the base, becoming clavate but not obovate in fruit: petals bright scarlet; the blade 8 lines in length, deeply bifid; the lobes more or less toothed: seeds smaller, smoother, and darker colored than in the preceding. — Gen. i. 288; Otth in DC. Prodr. i. 383; Torr. & Gray, Fl. i. 192. *Melandryum rotundifolium*, Rohrb. Monog. Sil. 234, & Linnæa, xxxvi. 257; Wats. Bot. King Exp. 431. — S. Ohio (acc. to Nuttall), Kentucky, and Tennessee, June to August.

S. regia, Sims. (Royal Catchfly.) Viscid-glandular above, finely pulverulent-pubescent below: stems tall, erect, rather rigid, simple or sparingly branched, leafy: leaves ovate, acuminate, 3–7-nerved from the rounded sessile base; the lowest more or less contracted below: flowers showy, in a narrow oblong panicle: calyx cylindrical, 10–12 lines long, becoming somewhat spindle-shaped in fruit: petals spatulate-lanceolate, subentire, scarlet. — Bot. Mag. t. 1724; Sweet's Brit. Fl. Gard. new ser. t. 313; Torr. & Gray, Fl. i. 193. *S. Virginica*, form, Michx. Fl. i. 272. *Melandryum regium*, A. Br. Flora, 1843, 372; Rohrb. Linnæa, xxxvi. 250. — Prairies, Ohio to Alabama and westward to Missouri, not abundant.

+ + Rocky Mountain and Pacific species.

++ Flowers large, rather few, scattered: calyx cylindrical or clavate in anthesis, 8–12 lines long: corolla (except in *S. Parishii*) usually more than 10 lines in breadth; petals 4–∞-cleft, very rarely bifid: stems leafy.

= Seed-coat more or less roughened but firm.

a. Corolla deep red.

S. laciniata, Cav. Finely pubescent: root narrowly fusiform: stems erect or decumbent, somewhat rigid, knotty below; the branches

ascending: leaves lanceolate to narrowly linear, scabrous, ciliolate, narrowed to a sessile base: flowers terminal on the branches: calyx subcylindric or clavate even in fruit, 10 lines in length: petals bright scarlet, 4-cleft or very rarely bifid: capsule oblong scarcely at all ovate, commonly exserted at maturity. — Icon. vi. 44, t. 564; Lindl. Bot. Reg. xvii. t. 1444; Gray, Pl. Wright. ii. 17; Wats. Proc. Am. Acad. x. 341. *S. pulchra*, Torr. & Gray, Fl. i. 675 in part. *S. speciosa*, Paxt. Mag. of Bot. x. 219. *S. simulans*, Greene, Pitt. i. 63. *Lychnis pulchra*, Cham. & Schlecht. Linnæa, v. 234.— Central California to New Mexico. (Mex.)

Var. Greggii, Wats. Leaves oblong-lanceolate to ovate, otherwise not differing essentially from the type. — Proc. Am. Acad. x. 341, & Bibl. Index, 108. *S. Greggii*, Gray, Pl. Wright. ii. 17. *Melandryum laciniatum*, var. *Greggii*, Rohrb. Monog. Sil. 232. *Melandryum Greggii*, Rohrb. Linnæa, xxxvi. 256. — New Mexico, *Wright*, *Thurber*, *Matthews*; Arizona, *Buckminster*, *Lemmon*. (Mex., *Gregg*.)

S. Californica, Durand. Root simple, strong, penetrating vertically to a depth of 2–3 feet: stems several, procumbent or suberect, leafy: leaves lanceolate or ovate elliptic, more or less narrowed to the base, acuminate, rarely obtusish: corolla more than an inch broad; petals variously cleft, most commonly with two broad lobes flanked by two narrower ones: capsule ovoid, concealed until dehiscence by the rather broad calyx. — Pl. Pratt. 83; Brew. & Wats. Bot. Calif. i. 64. *S. pulchra*, Torr. & Gray, Fl. i. 675 in part. *S. Virginica*, Benth. Pl. Hartw. 299. *S. laciniata*, var. *Californica*, Gray, Proc. Bost. Soc. vii. 146; Wats. Proc. Am. Acad. x. 341. *S. Tilingi*, Regel, Act. Hort. Petrop. i. 99. *Melandryum Californicum*, Rohrb. Linnæa, xxxvi. 252.— Coast Mts. of Currie Co., Oregon (*Howell*), southward through N. and Central California to Ft. Tejon (*Xanthus*), and perhaps farther. Subject to much variation in foliage, the following being perhaps the best marked of the varieties.

Var. subcordata. Leaves ovate, suborbicular, shortly acuminate, closely sessile by subcordate bases. — Blue Cañon, *Kellogg* (1870), *Brandegee* (1888).

b. Corolla white or nearly so.

S. Wrightii, Gray. Very glutinous: rootstock thick, ligneous: stems several, ascending, a foot or more in length, branching, leafy: leaves lanceolate, acuminate, 1½–2 inches long, sessile; the lower attenuate below: calyx teeth filiform-attenuate, nearly half as long as the tube: petals white, 4-cleft; the lobes somewhat toothed: capsule on a stipe of nearly its own length. — Pl. Wright. ii. 17; Wats. Bibl.

Index, 110. *Melandryum Wrightii*, Rohrb. Linnæa, xxxvi. 253; Wats. Bot. King Exp. 431. — Mountain sides near the copper mines, New Mexico, *Wright* (862).

S. **Hookeri**, Nutt. Covered above with a fine grayish pubescence: root single, stout: stems several, short, slender, decumbent: leaves oblanceolate, rather numerous and approximate, 2–3 inches in length, acute or obtusish: flowers very large: calyx teeth acute, but not filiform: petals 4-cleft, white or pink. — Nutt. in Torr. & Gray, Fl. i. 193; Bot. Mag. t. 6051; Fl. d. Serres, t. 2093; Wats. Proc. Am. Acad. x. 341; Brew. & Wats. l. c. i. 64. *S. Bolanderi*, Gray, Proc. Am. Acad. vii. 330, & viii. 378; Bolander, Cat. 6. *Melandryum Hookeri*, and *M. Bolanderi*, Rohrb. l. c.; Wats. Bot. King Exp. 431. — Woodlands, W. Oregon and N. W. California.

= = Seed-coat vesicularly roughened, or crested.

S. **Parishii**, Wats. Grayish pubescent: root simple, thick, with a branching rootstock: stems several, decumbent, a span long: leaves lanceolate, acuminate, sessile, 1–2 inches long; the lower oblanceolate: flowers aggregated at the ends of the branches: calyx tubular, narrowed below, an inch long, with narrow subulate teeth 3–4 lines in length: petals narrow, scarcely exserted from the calyx, cleft into 4 or more filiform segments: seeds doubly crested with short vesicular hairs. — Proc. Am. Acad. xvii. 366. — San Bernardino Mts., California, *S. B. & W. F. Parish.*

+ + Flowers smaller, not ordinarily exceeding 6–8 lines in diameter.

= Flowers borne in the forks of the branches forming a leafy inflorescence: calyx oblong or campanulate: leaves lanceolate or ovate.

S. **campanulata**, Wats. Finely glandular-pubescent: root thick, simple: rootstock branching, somewhat woody: stem slender, erect, leafy: leaves sessile, lanceolate: flowers on short deflexed peduncles: calyx green, broadly campanulate, reticulate-veined, toothed nearly to the middle: petals narrow; the limb cleft into 4 or more flesh-colored segments: capsule globular, 3–4 lines in diameter. — Proc. Am. Acad. x. 341; Brew. & Wats. l. c. i. 63. — Mountainous districts of N. California and S. Oregon.

Var. (?) **Greenei**, Wats. ined. More pubescent throughout: leaves ovate: petals greenish white. — Yreka, Calif., *Greene;* Cañonville and Wolf Creek, Oregon, *Howell Brothers;* Ashland, Oregon, *Henderson.* Apparently the commoner form.

S. **Menziesii**, Hook. Finely glandular-pubescent: stems weak, leafy, dichotomously branched above, 6 inches to a foot or more in

height: leaves ovate-lanceolate, acuminate at each end, thin: flowers very small: calyx obconical, obovate, or oblong, only 2½–4 lines in length: petals white, 2-cleft, commonly but not always unappendaged: capsule 1½–2 lines in diameter. — Fl. Bor.-Am. i. 90, t. 30; Torr. & Gray, Fl. i. 193 & 676; Rohrb. Monog. Sil. 147. *S. stellarioides*, Nutt. in Torr. & Gray l. c. i. 193. *S. Dorrii*, Kellogg, Proc. Calif. Acad. iii. 44, f. 12. — From Colorado to Vancouver Isl., S. California, and New Mexico.

= = Flowers few, rather small, white or nearly so, nodding, borne in a lax naked panicle: petals cleft into four or more narrowly linear, almost filiform segments: styles long-exserted: leaves small, lanceolate, chiefly clustered upon the more or less cespitose base.

S. longistylis, Engelm. Hoary-pubescent, minutely glandular above: root single: rootstock branched: stems 2–several, slender, 6–12 inches high, bearing 3–6 loosely paniculate or subracemose heads: leaves linear-lanceolate or oblanceolate, acute: calyx soon becoming ovoid: petals with a spatulate very pubescent, scarcely or not at all auriculate claw; the blade divided into 4 linear filiform segments; appendages linear, entire: capsule subsessile: seeds (apparently mature) small, dark red. — Engelm. in herb. Wats. Proc. Am. Acad. xxii. 469. — Scott's Mts., N. California, *Engelmann;* Ashland Butte, S. W. Oregon, *Henderson;* specimens collected in Plumas Co., Cal. (*Mrs. Austin*), and Mariposa Co. (*Congdon*), probably belong here also.

S. Lemmoni, Wats. Similar in habit: leaves broader, lanceolate, quite smooth or somewhat pubescent and glandular: calyx inclined to be herbaceous, especially the lanceolate acutish teeth, but the veins from the different nerves seldom anastomosing with each other: petals with a rather broad villous auriculate claw; the four divisions of the blade linear but not filiform: capsule nearly sessile: seeds red, somewhat irregular in shape, 1 line in length. — Proc. Am. Acad. x. 342; Brew. & Wats. l. c. i. 64. — California, Sierra Co., *Lemmon;* Janesville, *Brandegee;* Mariposa Co., *Congdon;* Coast Mts. north of San Francisco, *Rattan*. This species is too near the preceding and following, and it is not unlikely that more abundant material may show intergradation between them.

S. Palmeri, Wats. Similar in habit, more or less pubescent throughout, finely glandular above: leaves oblanceolate: calyx teeth commonly short and blunt, scarcely herbaceous; the base of the calyx often contracted about the short but distinct stipe of the ovary: the petals purplish; the claw villous, narrowly or broadly spatulate but

not auriculate; the limb deeply 4-cleft; the segments entire or bifid: seeds large for the genus, tuberculate, ash-colored at maturity. — Proc. Am. Acad. xi. 124; Brew. & Wats. l. c. i. 65. — S. California, Cucamaca Mts., *Palmer;* San Bernardino Mts., *Parish;* San Rafael Mts., *Ford.*

= = = Inflorescence as in the preceding: petals 2-cleft into linear segments: styles very long, the exserted portion as long as the calyx.

S. **Bridgesii**, Rohrb. Pubescent and viscid: stems leafy, usually simple up to the inflorescence, a foot or more in height: leaves sessile, lanceolate, acute, 1½–2 inches long: flowers slender-pedicelled, verticillately racemose or somewhat paniculate, nodding: calyx narrowly oblong or clavate in anthesis, broadly obovate in fruit; the teeth acute; the principal nerves broad, green; the commissural much narrower, seldom anastomosing with the others: petals ½–¾ inch long, considerably exserted, white or purplish: seeds very large, finely tuberculate, red. — App. Ind. Sem. Berol. 1867, 5, & Monog. Sil. 204; Wats. Proc. Am. Acad. x. 342; Brew. & Wats. l. c. i. 66. *S. incompta*, Gray, Proc. Am. Acad. vii. 330 = *S. Engelmanni*, Rohrb. Linnæa, xxxvi. 264, is a form of the same species, differing from the type only in the somewhat broader lobes of the petals and in the obtuse appendages. — Yosemite Valley, *Bridges, Gray;* Mt. Bullion, *Bolander;* Danah, *Congdon.* A closely similar if not identical plant has been found by *Rattan* on the Klamath River in N. California.

= = = = Flowers scattered, or variously paniculate: styles included or somewhat exserted, but not so long as in the preceding.

a. Fruiting calyx ovate, not contracted below, filled and distended by the subsessile capsule.

S. **Thurberi**, Wats. Densely grayish-pubescent and glandular: stems erect, 2 feet high, somewhat rigid, with ascending branches: leaves lanceolate, acute, contracted below, sessile, 2–4 inches long: flowers small, rather numerous: calyx cylindric becoming narrowly ovate, green-and-white striped, densely pubescent; the teeth slender with fimbriate laciniate margin: petals white, little exceeding the calyx; the claw rather broad with upwardly produced auricles; blade bifid with short oblong lobes, each with a small lateral tooth; appendages oblong, obtuse: capsule narrowly ovoid, scarcely stiped: seeds tuberculate and distinctly crested. — Proc. Am. Acad. x. 343. *S. plicata*, Wats. l. c. xvii. 366. — Near Janos, S. W. New Mexico, *Thurber;* peak south of Rucker Valley, *Lemmon.* (Mexico, *Pringle.*)

S. **pectinata**, Wats. Stems several, erect, 1½–2½ feet high: leaves lanceolate or oblanceolate, acute or acuminate; the lower long, tapering into winged petioles; the upper more or less reduced: flowers

purplish rose-colored, 6–8 lines broad: calyx becoming ovate in fruit: the teeth lance-linear to filiform, elongated, usually exceeding the mature capsule: petals with a narrow claw destitute of auricles; the blade obovate, bifid; the lobes rounded; the appendages lanceolate, entire: capsule large, ovate. — Proc. Am. Acad. x. 344; Brew. & Wats. Bot. Calif. i. 65. — Plumas Co., Calif., *Mrs. Ames;* Sierra Co., *Lemmon;* Carson City, Nev., *Anderson.* The typical form is very viscid glandular and somewhat branched.

Var. **subnuda.** Scarcely viscid: stems subsimple: radical leaves almost smooth, the cauline much reduced. — Near Empire City and at Franktown, Nev., *M. E. Jones.*

b. Capsule distinctly stiped: calyx relatively narrow, cylindric or in fruit clavate or obovate and usually rather distinctly contracted about the stipe of the capsule.

1. Petals 4 (–∞)-fid.

S. **Oregana,** Wats. Finely pubescent and very viscid, fetid: stems 1–several, erect, simple up to the racemiform or rather densely cymose-paniculate inflorescence: the lower leaves oblanceolate, narrowed below to long petioles; the upper leaves lanceolate or lance-linear, sessile: petals white with spatulate claws, glabrous, distinctly auricled at the summit; the blade 2–3 lines long, variously cleft into 4–6 or more linear segments: the stipe of the ovoid capsule about 2 lines long. — Proc. Am. Acad. x. 343; Brew. & Wats. l. c. i. 65. — Mountains of Oregon, Washington, and Montana, April to August.

S. **montana,** Wats. Finely pubescent: stems erect from a more or less decumbent base, 4–14 inches high: leaves lance-linear or narrowly oblanceolate, acuminate, 1–2½ inches in length; the cauline 3–4 pairs: inflorescence varying from subspicate to paniculate; flowers rarely solitary: calyx 6–9 lines in length: petals greenish white to rose-colored, exserted 2–4 lines: ovary long-stiped: capsule acutish. — Proc. Am. Acad. x. 343. — Near Carson City, Nev., *Anderson;* Sierra Co., Cal., *Lemmon.* *S. Shockleyi*, Wats. l. c. xxv. 127, from the White Mts., Mono Co., Cal., is apparently only a high-mountain form of the same species.

Var. **rigidula.** Stems simple, a span high, slightly rigid: leaves short, less than an inch in length, thickish and stiff: flowers white, subspicate. — Franktown, Nev., *M. E. Jones*, 1882.

S. **occidentalis,** Wats. Viscid-glandular, 2 feet high: stems one or two from a single strong root, branched above: leaves lanceolate or oblanceolate, 2–3 inches long: flowers in a very loose open panicle: calyx elongated, cylindric becoming clavate in fruit: petals purple,

4-cleft into lanceolate segments; the blade narrowed gradually into the cuneate claw, the latter devoid of auricles; appendages linear: capsule oblong, upon a stipe 2 lines in length. — Proc. Am. Acad. x. 343; Brew. & Wats. l. c. i. 64. — Calif., *Bolander*, without special locality; Plumas Co., Calif., *Lemmon*, *Mrs. Austin;* Butte Co., *Mrs. Bidwell.*

2. Petals bifid, each lobe sometimes bearing a very small lateral tooth.

S. purpurata, Greene. "Stems numerous, from slender running rootstocks, 6–18 inches high, rather slender: whole plant pubescent and slightly viscid: leaves rather remote, linear-lanceolate, acute, 1½ inches long: flowers in terminal and subterminal peduncled or subsessile cymes of about 3: calyx purple, rugose-veiny, clavate, not inflated, ½ inch long or more; limb of petals more than half as long, white or pink, obcordate or bifid, appendaged at base." — This species, not seen by the author, appears to be near *S. Scouleri*, Hook. The description is drawn from Pittonia, ii. 229. — Porcupine River, interior of N. Alaska, *J. H. Turner.*

S. verecunda, Wats. Low, 6–12 inches in height, finely pubescent below, glandular-viscid above: stems several, leafy especially near the base: leaves narrowly lanceolate or oblanceolate to linear, acute: flowers rather few, mostly terminal or subterminal; the branches of the inflorescence erect: calyx soon becoming strongly obovate by the development of the broad ovoid capsule: calyx teeth with membranous ciliated margins: petals rose-colored; the claw glabrous, narrowly auricled; the blade 2-cleft into short entire oblong segments; appendages oblong, blunt and somewhat toothed at the apex. — Proc. Am. Acad. x. 344; Brew. & Wats. l. c. i. 65. *S. Engelmanni*, var. *Behrii*, Rohrb. Linnæa, xxxvi. 264. — Central California near the coast, Mission Dolores, San Francisco.

S. Luisana, Wats. Taller, finely pubescent: stems several from a branching caudex, erect, slender, viscid above: leaves narrowly oblanceolate to linear, acute, most numerous at the base; the cauline gradually reduced: flowers borne upon short spreading peduncles: fruiting calyx clavate; teeth long and narrow, with an incurved membranous ciliated margin: petals white, with narrowly auricled glabrous claw, and 2-cleft blade; segments linear-oblong, entire or with a small lateral tooth; appendages lanceolate, often toothed: capsule cylindric. — Proc. Am. Acad. xxiii. 261. — California, San Luis Obispo, *J. G. & S. A. Lemmon;* near Tolon, *Brandegee;* mountains south of Ft. Tejon, *Coville & Funston.*

S. platyota, Wats. Minutely pubescent throughout, glandular above: root thick: stems slender, 1½ feet high: leaves oblanceolate,

p ... inflorescence
tl ... individuals some-
n ... in fruit, with
bl ... ciliated margins:
e ... diameter: the
W ... the base, with
L ... ; the short ob-
v ... appendages lance-
... Cuyamaca Mts.,
al. ... *Parish Bros.*,
F ... Lower Calif.) A very
... San Bernardino Mts.,
b. ... and a calyx with blunter

... pubescent: stems nu-
... near or nearly so, 1 to
1– ... the radical crowded,
pa ... and imbricated bases;
to ... long; teeth short: the
pe ... broad laciniately cleft
sun ... segments each bearing a
line ... , and very slender,
Pro ... diameter: seeds tuberculate-
Ore ... Acad. xiv. 290. — Table
S ... S. Sargent.
or l ... rather loosely surround-
row ... not distinctly contracted
pairs
rarely ... appendages fringe-toothed.
rose-
— Pr ... fine grayish pubescence
Sierra ... : stems several, slen-
White ... : leaves grass-like,
of the ... developing first, the
Var. ... : buds acute: calyx
short, l ... membranous ciliated
spicate. ... the claw with broad
S. oc ... inner ones broad and
or two f ... Am. Acad. xxiv. 82. —
oblanceol ... Calif., *Palmer.*
calyx elo

2. Petals bifid; each segment with or without a smaller lateral tooth.

1* Low, 3–8 inches in height.

S. Grayii, WATS. — Cespitose, minutely pubescent and glandular: rootstock elongated, much branched: stem simple, erect, 4–6 inches high, 1–5-flowered; leaves short, oblanceolate or spatulate, slightly fleshy, 4–8 lines in length, the radical numerous, crowded; the cauline about 3 pairs: calyx broadly cylindrical: the teeth rounded; petals pink, with blade deeply bifid, and segments each bearing a lateral tooth; claw narrowly auricled: capsule short ovoid, scarcely stiped. — Proc. Am. Acad. xiv. 291; Robinson, Bot. Gaz. xvi. 44, t. 6. — Mt. Shasta above the timber line and near snow, *Brewer*, *Hooker & Gray*, *Packard*, *Pringle*. Specimens collected on Mt. Rainier by *E. C. Smith*, and having somewhat longer leaves, may be doubtfully referred to this species.

S. Watsoni. Finely glandular above, minutely pubescent, nearly smooth below: stems many, cespitose from a multicipital caudex, erect, very slender, simple, 4–8 inches in height, bearing 1–3 (rarely 5) flowers: leaves linear or very narrowly oblanceolate, acute, dark green; the radical numerous, an inch in length, seldom exceeding a line in breadth: the slender petioles expanding at the base, closely imbricated and connate by scarious membranes: calyx ovate or somewhat obovate, 5–6 lines in length, with purple more or less anastomosing nerves; the teeth with membranous margins: petals white or rose-colored: the blade short, a line in length, bifid; each segment usually bearing a short lateral tooth; appendages obtuse: styles ordinarily 3, rarely 4. — *Lychnis Californica*, Wats. Proc. Am. Acad. xii. 248. — California, near Ebbett's Pass, *Brewer*; Mt. Dana, *Bolander*; Sierra and Plumas Cos., *Lemmon*. As in *S. Lyallii*, the anthers are often infested by *Ustilago antherarum*, and in consequence enlarge and turn purple.

S. Suksdorfii, ROBINSON. Low, densely matted, alpine: stems 2–3 (rarely 4–5) inches high, simple 1–3-flowered, minutely pubescent below, glandular above: stem leaves about 2 pairs, linear, 3–7 lines long, a line wide; radical leaves numerous, crowded, similar or somewhat spatulate: calyx broadly cylindric or campanulate, seldom exceeding 5 lines in length; nerves conspicuous, simple below, anastomosing above: petals white, little exceeding the calyx, shallowly bifid; lobes entire; appendages oblong, retuse: stipe of capsule 1½ lines long. — Bot. Gaz. xvi. 44, t. 6. — California to Washington, Mt. Stanford, *Hooker & Gray*; Mt. Paddo, *Suksdorf*; Mt. Hood *Howell*; Mt. Stewart, *Brandegee*; Mt. Rainier, *Piper*.

IX.

CONTRIBUTIONS FROM THE GRAY HERBARIUM OF HARVARD UNIVERSITY, NEW SERIES.

V.—THE NORTH AMERICAN SILENEÆ AND POLYCARPEÆ.

By B. L. Robinson.

Presented April 12, 1893.

The following study of the *Sileneæ* and *Polycarpeæ* is preliminary to treatment of these tribes of the *Caryophyllaceæ* in the "Synoptical Flora of North America." The object of the present publication is chiefly to secure aid through criticisms, and to call attention to such species, especially in the genera *Silene* and *Lychnis* as are still imperfectly known, so that if possible more complete material of them may be secured before final revision for the first volume of the Synoptical Flora. Specimens of these groups, especially puzzling forms from the West and Northwest, together with notes concerning any points not properly covered by the following descriptions, will be gratefully received by the author, who here cordially acknowledges the valuable assistance already rendered him in his work by the late Dr. George Vasey and Dr. J. N. Rose, of the Department of Agriculture; Prof. N. L. Britton of Columbia College; Mr. and Mrs. T. S. Brandegee and Miss Alice Eastwood, of the California Academy of Sciences; Prof. John Macoun, of the Canadian Geological Survey; Mr. John H. Redfield, of the Philadelphia Academy of Natural Sciences; Mr. John Donnell Smith, and others, whose names are mentioned in the text. In the enumeration of synonyms and the citation of literature Dr. Sereno Watson's "Bibliographical Index" has been a most useful guide; so far as possible, however, all references to literature as well as points of synonymy, from whatever source, have been subjected to careful verification.

CARYOPHYLLACEÆ, Tribe I. SILENEÆ. Sepals united into a 4–5-toothed or lobed tube or cup. Petals unguiculate and often scale-bearing at the junction of the blade and claw, borne together with

the stamens upon the stipe of the ovary. Stipules none. Flowers usually showy, perfect or not infrequently polygamous.

* Calyx subtended by 1–several pairs of bractlets: flowers solitary or often aggregated in close heads: seeds flattened and attached by the face: embryo nearly straight.

1. **Dianthus.** Calyx tubular, 5-toothed, finely many-striate. Petals 5, with long claws; the blade entire, emarginate, or several-toothed. Stamens 10. Styles 2. Capsule 1-celled, dehiscent by 4 valves. Leaves narrow, often connate by narrow scarious membranes. Flowers commonly showy.

2. **Tunica.** Calyx turbinate or cylindrical, obtusely toothed, distinctly 5-ribbed, or sometimes 15-ribbed. Petals 5. Stamens 10. Styles 2. Flowers considerably smaller and habit more slender than in *Dianthus*.

* * Calycine bractlets none: seeds laterally attached: embryo curved.

+– Styles 2: capsule 4-toothed or valved: introduced plants.

3. **Gypsophila.** Calyx turbinate, tubular or campanulate, 5-toothed, herbaceous only in the middle of the segments, the intermediate parts being scarious. Petals 5. Stamens 10. Flowers mostly small, paniculate or scattered, rarely aggregated. Capsule rather deeply 4-valved.

4. **Saponaria.** Calyx tubular or ovoid, 5-toothed, terete with numerous faint veins, or conspicuously 5-angled. Flowers showy. Petals 5. Stamens 10. Capsule dehiscent at the apex by 4 short teeth.

+– +– Styles normally 3; capsule opening by 3 or 6 teeth: calyx commonly 10-nerved, rarely ∞-nerved.

5. **Silene.** Calyx 5-toothed, campanulate, subcylindric or turbinate, either inflated or becoming distended by the maturing capsule, 10–∞-nerved. Petals usually appendaged at the summit of the claw; the blade variously toothed or divided, rarely entire. Stamens 10. Styles 3 (very rarely 4). Stipe of the ovary commonly developed. The capsule 1-celled or somewhat 3-celled at the base. Flowers solitary, racemose, or cymose-paniculate.

+– +– +– Styles 5 (rarely 4), alternating with the petals when of the same number: calyx teeth short, not foliaceous.

6. **Lychnis.** Calyx ovoid, obovate, or clavate, 5-toothed, 10-nerved, inflated or not. Petals with or without appendages; the blade entire, emarginate, bifid or variously cleft. Stamens 10. Ovary 1-celled, or divided at the base into 5 (rarely 4) partial cells. Capsule dehiscent by as many or twice as many teeth as there are styles.

← ← ← ← Styles 5, opposite the petals: calyx teeth conspicuously prolonged into foliaceous appendages.

7. **Agrostemma.** Calyx ovoid, with 10 strong ribs; the elongated teeth in our introduced species an inch or more in length, exceeding the 5 large unappendaged petals. Stamens 10. Capsule 1-celled. Leaves linear.

TRIBE II. ALSINEÆ. Sepals free or nearly so. Petals not distinctly unguiculate, never appendaged. Styles 2–5, distinct to the base. — Including genera 8–14; to be published at an early date.

TRIBE III. POLYCARPEÆ. Sepals free or somewhat united at the base. Petals commonly small, not distinctly unguiculate, borne together with the stamens upon an hypogynous or slightly perigynous disk. Style simple below, 3- or more rarely 2-branched above. The stigmas rarely sessile on the ovary.

* Petals 2–5-parted.

15. **Drymaria.** Sepals 5, often scarious-margined. Petals 5. Stamens 3–5, slightly perigynous. Ovary 1-celled, several–many-ovuled. Capsule 3-valved. Flowers small, greenish white. Leaves flat, though often narrow, opposite or pseudoverticellate. Stipules small, free, scarious or bristle-formed, sometimes fugacious.

* * Petals entire, denticulate, or none.

← Cauline leaves numerous, flat, not linear-setaceous.

16. **Polycarpon.** Sepals 5, more or less carinate, entire, scarious-margined. Petals 5, small, shorter than the sepals, sometimes emarginate. Stamens 3–5. Ovary 1-celled. Capsule 3-valved, several-seeded. Seeds ovoid with the embryo but little curved.

← ← Cauline leaves setaceous.

17. **Lœflingia.** Sepals 5, carinate and produced to rather rigid setaceous tips; the three outer ones commonly bearing a setaceous tooth on each side. Petals 3–5, small or none. Stamens 3(–5 ?). Ovary 1-celled, several-seeded, triangular. Capsule 3-valved. Seeds oblong, attached laterally near the base. Embryo somewhat curved. Cotyledons accumbent.

← ← ← Leaves forming a radical rosette; the cauline minute or obsolete: basal stipules lacerate.

18. **Stipulicida.** Sepals 5, distinct, somewhat rigid, obtuse, emarginate, scarious-margined. Petals 5, entire, narrowly oblong, gradually contracted below, hypogynous. Stamens 5. Capsule ovate-globose, 3-valved, many-seeded.

1. DIANTHUS, L. Pink, Carnation. (Διός and ἄνθος, flower of Jove.) — Chiefly natives of S. Europe and N. Africa, deservedly popular in cultivation. — Gen. n. 364; DC. Prodr. i. 355; Reichb. Icon. Fl. Germ. vi. t. 248–268; Benth. & Hook. Gen. i. 144. — Several species tend to escape and have become more or less naturalized. One variety only is indigenous to this continent.

* Indigenous in the extreme Northwest.

D. alpinus, L. Low cespitose perennial with numerous ascending 1-flowered stems: bracts 2–6, erect or somewhat spreading. — Spec. 412; Regel, Ost-Sib. i. 284. — (Eur., Siberia.) Very variable and according to Regel passing into the following.

Var. repens, Regel. Root single, vertical or descending, not repent: stems procumbent, much branched from near the base: branches simple, ascending, 3–6 inches in height, most often 1-flowered: leaves linear or linear-lanceolate, 8–16 lines long, glabrous, slightly fleshy: involucral scales a single pair, narrowly ovate, acuminate, nearly equalling the calyx, the attenuated tips slightly spreading: calyx somewhat inflated, 6 lines long: corolla purple, about 7 lines broad, glabrous, the obovate blade erose-dentate. — Regel, l. c. 286. *D. repens*, Willd. Spec. ii. 681; Cham. et Schlecht. Linnæa, i. 37; Torr. & Gray, Fl. i. 195; Seem. Bot. Herald, 27, t. iv. — Northern and western coast of Alaska. (Siberia.)

* * Adventive from Europe and more or less established in various localities in the Eastern and Middle States.

+ Bractlets short, half the length of the calyx: flowers solitary.

D. deltoides, L. (Maiden Pink.) Perennial: stems decumbent, ascending, a foot in height, very leafy below: leaves short, lanceolate, a line wide, the lower obtusish, the uppermost acute: calyx long, tubular: petals narrow, pink or white. — Spec. 411; Eng. Bot. i t. 61; Gray's Man. ed. 6, 83. — Occasionally found escaped from gardens, New England to Michigan.

+ + Bractlets narrow, attenuate, equalling or exceeding the calyx: flowers clustered.

D. barbatus, L. (Sweet William.) A smooth perennial, 1–2 feet in height: stems simple, bearing the flowers in dense cymose fascicles: leaves lanceolate, large for the genus, 1½–3 inches long, a fourth as wide, minutely roughened on the edges: bractlets filiform from a lanceolate base: blade of petals triangular-obovate, toothed, red, purple or white, often variegated in cultivation. — Spec. 409; Reichb. Icon. Fl. Germ. vi. t 248. — Long cultivated and occasionally spontaneous about old gardens.

D. ARMERIA, L. (DEPTFORD PINK.) Annual, 1–2 feet high, covered with a fine grayish pubescence: stems branching and bearing several 2–4-flowered fascicles: bracts subulate, attenuate, villous: flowers scentless: calyx slender, tubular, 7–8 lines long, the teeth very sharp: petals roseate, spotted with white; the blade elliptical, crenate-dentate. — Spec. 410; Pursh, Fl. 314; Bigel. Fl. Bost. 108; Torr. Fl. N. & Mid. St. 447; Torr. & Gray, Fl. i. 195. *D. armeroides*, Raf. in Desv. Journ. Bot. 1814, 269; Précis des Decouv. 36. *Atocion armerioides*, Raf. Autikon Bot. 29. *D. Carolinianus*, Walt. Car. 140, referred here by Sprengel, Syst. ii. 375, was without doubt founded upon error. Torrey & Gray, Fl. i. 676, state that Walter's own specimen was *Dodecatheon Meadia.* — Fields and pine woods, Eastern States from Maine (Portland Catalogue) to Maryland; Lansing, Michigan, *L. H. Bailey;* fl. June and July. Autumnal flowers in October noted by *L. F. Ward.*

+ + + Bractlets broad, scarious, concealing the calyx.

D. PROLIFER, L. Annual, a foot or two in height: stems wiry: leaves narrow, minutely scabrous, acute: heads terminal, 2–several-flowered, enclosed in thin dry ovate obtusish mucronate imbricated bractlets: flowers expanding one at a time, ephemeral: calyx tubular; the veins faint, collected into five groups: petals small, notched, pink or red. — Spec. 410; Eng. Bot. xiv. t. 956. *Tunica prolifera*, Scop. Fl. Carn. ed. 2, i. 299. — New Jersey, *Durand;* Eastern Pennsylvania, *Smith, Porter;* Suffolk Co., N. Y., *Hollick;* fl. all summer. This species, especially in its calyx, forms a transition to the next genus.

2. TUNICA, Scop. (*Tunica*, a tunic, probably in reference to the close involucre.) Slender wiry-stemmed herbs with small mostly linear leaves. Flowers terminal, solitary or fascicled in small heads. — Fl. Carn. ed. 2, i. 298; Benth. & Hook. Gen. i. 145; Williams, Journ. of Bot. xix. 193 (1890). — Old World plants represented in America by a single species recently introduced.

T. SAXIFRAGA, Scop. Smooth: stems numerous, slender, branching, curved ascending: leaves small, linear, acute, less than half a line in width: the lower internodes very short: flowers small, numerous, terminal, solitary: bractlets 2 pairs, scarious except in the middle, acute, considerably shorter than the calyx: petals notched, pale purple; the blade a line in length. — Scop. l. c. i. 300; Reichb. Icon. Fl. Germ. vi. t. 246. — Roadsides near London, Ontario, *Burgess.* (Adventive from Europe.)

3. GYPSOPHILA, L. (γύψος, gypsum, and φιλεῖν, to love, from a supposed preference for soil rich in gypsum.) — Old World

herbs of graceful habit, mostly natives of Southern Europe and Western Asia. Several species are cultivated for ornament; the following are sparingly naturalized. — Gen. ed. 4, n. 498; DC. Prodr. i. 351 in part; Reichb. l. c. vi. t. 239–242; Benth. & Hook. Gen. i. 146; Williams, Journ. of Bot. xviii. 321.

G. MURALIS, L. Low, annual, with the habit of *Arenaria*: leaves small, linear, acute: flowers scattered in the forks of the branches: pedicels filiform, two or three times as long as the calyx: petals pink with darker veins, emarginate, 2–3 lines in length. — Amœn. Acad. iii. 24; Spec. ed. 3, 583; Fl. Dan. viii. t. 1268. — Ballast and roadsides, New Jersey, *Brown*; Montague, Mass., *Churchill*; Wethersfield, Conn., *Wright*; London, Canada, *Dearness*. Introduced (N. and Mid. Europe and Siberia).

G. PANICULATA, L. l. c. Perennial, glabrous and somewhat glaucous, 2 feet or more in height: leaves lanceolate, acute, 1–1½ inches in length: flowers very numerous in a compound panicle: segments of the calyx with conspicuous white scarious margins: petals scarcely exceeding the sepals: capsule nearly spherical. — Reichb. l. c. vi. t. 242. — Doubtfully established, Emerson, Manitoba, *Fowler*. (Adventive from Europe.)

4. SAPONARIA, L. SOAPWORT. (From *sapo*, soap; *S. officinalis* having been used as a substitute for soap, the juice being capable of forming a lather.) — A genus of the Old World including plants of diverse habit. Two rather coarse species belonging to different sections of the genus are spontaneous in America. — Gen. n. 365; DC. Prodr. i. 365; Benth. & Hook. Gen. i. 146.

S. VACCARIA, L. A smooth annual with ovate or oblong-lanceolate, sessile and somewhat connate leaves: flowers in a broad flat corymb: calyx ovoid, with 5 sharp herbaceous angles, the intervening parts being white and scarious: corolla rose-colored, destitute of appendages. — Spec. 409; Bot. Mag. t. 2290; Torr. & Gray, Fl. i. 195; also variously referred by authors to *Gypsophila*, *Lychnis*, or more often regarded as an independent genus, *Vaccaria*. — Railway ballast and cultivated ground, frequent and sometimes troublesome in wheatfields westward, where it bears the name of "cockle." July–August. (Introduced from Europe.)

S. OFFICINALIS, L. (SOAPWORT, BOUNCING BET.) Perennial, smooth, 1½–2 feet high: leaves ovate-lanceolate, acute, 3-ribbed, 2–3 inches long, narrowed at the base; inflorescence terminal, somewhat pyramidal, the flowers clustered at the ends of short branches: calyx tubular, terete: petals appendaged at the junction of the claw and the

obovate retuse blade, white or pink, often double. — Spec. 408; Eng. Bot. xv. t. 1060; Pursh. Fl. 314; Torr. & Gray, Fl. i. 195. — Roadsides and waste ground, common; July to the end of October. (Naturalized from Europe.)

5. SILENE, L. CATCHFLY, CAMPION. (Name from Σειληνός, in reference to the viscid excretion of many species, the Greek god having been described as covered with foam; also derived directly from σίαλον, saliva.) — A large genus of attractive plants inhabiting chiefly the northern temperate parts of the Old World, but also well represented in North America, especially in the Pacific region, where it has lately been necessary to increase considerably the number of species. Although the members of the genus present considerable diversity of habit and floral characters, yet they do not fall into well marked groups and the elaborate subdivision of the genus suggested by Rohrbach cannot be satisfactorily carried out among our American species. — Gen. n. 372; Otth in DC. Prodr. i. 367; Torr. & Gray, Fl. i. 189; Fenzl in Ledeb. Fl. Ross. i. 303; Reichb. Icon. Fl. Germ. vi. t. 269–301; Benth. & Hook. Gen. i. 147; Rohrb. Monog. der Gatt. Silene; Wats. Proc. Am. Acad. x. 340, & Bibl. Index, 106.

* Annuals, mostly introduced.

+ Inflorescence simply racemose, or subspicate; pedicels solitary.

S. GALLICA, L. Stem hirsute with white jointed hairs: leaves spatulate, obtuse, mucronate, hirsute-pubescent on both sides, 8–18 lines in length: racemes terminal, one-sided, 2–4 inches long: flowers more or less pedicellate: calyx 10-nerved, villous-hirsute, slender and subcylindric in anthesis, becoming in fruit broadly ovoid, with contracted orifice and short narrow spreading teeth: petals usually little exceeding the calyx; the blade obovate, somewhat bifid, toothed or entire. — Spec. 417; Cham. & Schlecht. Linnæa, i. 40; Rohrb. l. c. 96. *S. Anglica*, L. l. c. 416. — Apparently of European origin but now cosmopolitan; locally common on the Pacific slope from British Columbia to Lower California; occasionally in cultivated fields in the Atlantic States; April–July. The typical form has very short ascending pedicels and white or pink flowers. S. LUSITANICA, L. l. c. 416, is a form with the lower pedicels elongated, equalling or exceeding the calyx, and becoming horizontal in fruit. Tolon, Calif., *Brandegee*. (Europe.)

Var. QUINQUEVULNERA, Koch. Petals more showy, subentire, deep crimson with a white or pink border. — Synop. Fl. Germ. et Helv. 100. *S. quinquevulnera*, L. l. c. 416. — With the typical form.

S. NOCTURNA, L., although credited to this country by Torr. & Gray and by various subsequent authors, is not represented from America in the leading herbaria of the country. Most if not all of the specimens referred here are either *S. Gallica* or *S. noctiflora*.

← ← Inflorescence dichotomously racemose.

S. DICHOTOMA, Ehrh. Tall, more or less hirsute and viscid: root annual or biennial: leaves lanceolate or oblanceolate: flowers short-pedicelled or subsessile, larger than in the preceding, ½ inch in diameter: petals white or roseate, the blade obovate, more or less deeply bifid: calyx cylindric in anthesis, becoming ovate in fruit, the prominent green nerves strictly simple, hirsute. — Beitr. vii. 143. Reichb. l. c. vi. t. 280. — A European species somewhat intermediate between *S. Gallica* and *S. noctiflora*; ballast and waste land, Philadelphia, *Martindale*; Trenton, *Volk*; Texas, *Nealley*. The form RACEMOSA, Rohrb., *S. racemosa*, Otth in DC. Prodr. i. 384, with more pubescent leaves tending to be clustered about the base has been found by *Prof. Greene* sparingly introduced in fields about Berkeley, Cal. Fl. Francis. i. 116.

← ← ← Inflorescence cymose or paniculate, not distinctly racemose.

↔ Calyx equally and conspicuously 20–25-nerved.

S. **multinervia**, WATS. Erect, a foot high, pubescent throughout and somewhat viscid-glandular above: leaves narrowly oblong or linear, acute: inflorescence cymose with unequal branches: calyx ovate in fruit, contracted above, 5 lines long: petals small, purplish, unappendaged, not exceeding the subulate spreading calyx teeth: capsule narrowly ovate. — Proc. Am. Acad. xxv. 126; Zoe, i. 254. — Southern California, near Jamuel, *Orcutt*; island of Santa Cruz, *Brandegee*; Santa Monico Range, *Hasse*. This anomalous species is strongly characterized among indigenous Silenes by its many-nerved calyx, which places it in the Mediterranean § *Conosilene*. The California botanists are inclined to regard it as an introduced plant, and Davidson, in Erythea, i. 58, erroneously reduces it to *S. conoidea*, of the Old World, a species which differs in its larger flowers, longer and more attenuate calyx teeth, and long-necked flask-shaped capsules.

↔ ↔ Calyx 10-nerved.

= Viscid-pubescent or hirsute.

S. NOCTIFLORA, L. A coarse species a foot or two in height with lanceolate or ovate-lanceolate leaves 2–3 inches long: flowers usually few in loose cymes, fragrant: calyx large, in fruit ovoid, white with green nerves tending to anastomose: the teeth attenuate: petals bifid. — Spec. 419; Eng. Bot. v. t. 291; Torr. & Gray, Fl. i. 192; Gray's

Man., ed. 6, 85. — Roadsides and cultivated grounds, June to September. (Nat. from Eur.)

= = Smooth or nearly so, a part of each of the upper internodes glutinous.

S. antirrhina, L. (SLEEPY or SNAPDRAGON CATCHFLY.) Stem 6 inches to 3 feet in height: leaves oblong-lanceolate or linear, commonly acute: flowers rather numerous, small, ephemeral, borne in a compound cyme; pedicels long, filiform: calyx smooth, green, ovoid in fruit, about 4 lines long, contracted above; the teeth short: ovary scarcely stiped: petals small, pink or white, more or less emarginate or bifid. — Spec. 419; Otth in DC. Prodr. i. 376; Torr. & Gray, Fl. i. 191; Rohrb. l. c. 173; Mart. Fl. Bras. xiv. 2, t. 66. *Saponaria dioica*, Cham. & Schlecht. Linnæa, i. 38. — Waste places, common, widely distributed throughout the United States and Canada (also S. Am.); very variable in size and foliage.

Var. linaria, WOOD. "Very slender: leaves all linear except the lowest which are linear-spatulate; calyx globular. Ga. and Fla." — Wood, Class-Book, ed. of 1861, 256, & Bot. & Fl. 53; Wats. Bibl. Index, 107.

Var. divaricata. Very slender: leaves linear or lance-linear, not exceeding an inch in length: branches filiform divaricate: calyx ovoid, 2–2½ lines long; petals wanting. — Rockford, Ill., *M. S. Bebb, G. D. Swezey.*

S. ARMERIA, L. Leaves elliptic or ovate-elliptic: flowers borne at the ends of the branches in small close cymes: pedicels short: calyx slender, clavate, 6–8 lines long: ovary long-stiped: petals pink, subentire or minutely toothed; appendages lanceolate acute. — Spec. 420; Torr. & Gray, Fl. i. 194; Reichb. l. c. vi. t. 284. — Occasionally found on roadsides and in fields, having escaped from gardens.

* * Perennial, subacaulescent, very low and densely matted.

S. acaulis, L. (MOSS CAMPION.) Closely cespitose, an inch or two in height: leaves linear, crowded on the branching rootstocks: flowers small, 2–3 lines in diameter, subsessile or raised on naked curved peduncles 2–6 lines long: calyx narrowly campanulate, 2–3 lines long, glabrous; the teeth short, rounded: petals purplish, rarely white, entire, retuse or bifid, minutely appendaged. — Spec. ed. 2, 603; Reichb. Icon. Fl. Germ. vi. t. 270. *Cucubalus acaulis*, L. Spec. 415. *Lychnis acaulis*, Scop. Fl. Carn. ed. 2, i. 306. — An arctic and high alpine species, widely distributed and somewhat variable. Arctic America to the White Mts.; extending along the Rocky Mts. from Alaska to Arizona, also found in the Cascade Mts. (Eur. and Asia.) A some-

what caulescent form, with very slender elongated leaves 1–1½ inches in length, has been found in the Rocky Mountains of Colorado, *Miss Eastwood*, and Arizona, *Rothrock*. It is connected, however, with the typical form by gradual transitions.

* * * Caulescent perennials.

+ Eastern and Southern species.

++ Calyx inflated, flowers white or pink, scattered or panicled.

S. Cucubalus, Wibel. (Bladder Campion.) Glaucous: stems ascending, a foot or more in height, leafy below, smooth or somewhat rough-pubescent: leaves opposite, usually lanceolate, acute: bracts much smaller: flowers polygamo-diœcious: calyx campanulate to subglobose, strongly inflated, glabrous, finely reticulated between the inconspicuous nerves: petals narrow, 2-cleft, scarcely crowned, white or pink. — Prim. Fl. Werth. 241; Rohrb. l. c. 84; Gray's Man. ed. 6, 84. *S. inflata*, Smith, Fl. Brit. ii. 467; Gray's Man. ed. 5, 89; Warming, Bot. Foren. Festskr. 1890, 258. *Cucubalus Behen*, L. Spec. 414. — Fields and roadsides, New Brunswick to Illinois. (Nat. from Europe.)

S. nivea, Otth. Stem smooth or minutely pubescent above, 1½–3 feet in height: leaves opposite, lanceolate, attenuate-acuminate, smooth or pulverulent-pubescent: flowers rather few, nodding, borne in the forks of the branches: bracts foliar: calyx oblong in anthesis, fine-pubescent or smooth; nerves inconspicuous, anastomosing, the teeth short, triangular, obtuse: petals cuneate-obovate, bearing two short blunt appendages. — Otth in DC. Prodr. i. 377; Torr. & Gray, Fl. i. 190; Rohrb. l. c. 87. *S. alba*, Muhl. Cat. 45 (nomen subnudum). *Cucubalus niveus*, Nutt. Gen. i. 287. — Pennsylvania and Washington, D. C., to S. Illinois, Iowa, and Minnesota; rare.

S. stellata, Ait. (Starry Campion.) Stems 2–3 feet high: leaves in whorls of 4 (the lowest sometimes opposite), ovate-lanceolate, acuminate, 2–3 inches long, half as broad: flowers in an open panicle: calyx campanulate, 4–5 lines in length; the teeth broad, acuminate: petals laciniately cleft, unappendaged. —Kew. ed. 2, iii. 84; Torr. Fl. N. Y. i. 100, t. 16. *Cucubalus stellatus*, L. Spec. 414; Sims, Bot. Mag. t. 1107. — Woodland, frequent, S. New England to Minnesota, southward to Virginia and Texas.

++ ++ Calyx not inflated, distended only by the enlarging capsule.

= Flowers white or rose-colored.

S. ovata, Pursh. Pubescent or smooth: stems several from the same root, 2–4 feet in height; leaves ovate to ovate-lanceolate, attenuate-acuminate, 3–5 nerved from the rounded base, sessile, subconnate, 3–5 inches long: flowers borne in a narrow terminal leafless panicle:

calyx tubular, 3–4 lines in length, 10-nerved: petals white, the blade dichotomously cleft into linear segments. — Fl. i. 316; Torr. & Gray. Fl. i. 190; Chapm. Fl. 51. *Cucubalus polypetalus*, Walt.? Car. 141. — Alluvial woods, uplands, North Carolina to Georgia and Alabama.

S. Baldwinii, Nutt. Villous: stems low, weak, decumbent, throwing out runners: lower leaves spatulate obtuse, with an attenuate base; the upper oblanceolate or lanceolate, acute: flowers few, very large, 1½ inches or more in diameter, pedicellate, aggregated at the ends of the stems: calyx clavate, pubescent, 10 lines in length; the teeth ovate-lanceolate, acuminate: petals white or pink, the large obovate blade fringed, unappendaged. — Gen. i. 288; Torr. & Gray, Fl. i. 193; Chapman, Fl. 51. *S. fimbriata*, Bald. in Ell. Sk. i. 515, not of Sims. *Melandryum Baldwini*, Rohrb. l. c. 231; Wats. Bot. King Exp. 431. — Georgia and Florida, March to May.

S. nutans, L. Stems slender, a foot or more in height, leaves mostly at the base, spatulate; the cauline small, lanceolate: flowers in a slender, little branched panicle, nodding, 6–7 lines in diameter: calyx cylindrical in anthesis, not exceeding 5 lines in length: petals white or rose-colored, bifid (rarely 4-fid), segments narrow: capsule large ovate-conical. — Spec. 417; Reichb. l. c. vi. t. 295. — Introduced on Mt. Desert, *Miss Minot.* (Europe and Siberia.)

S. Pennsylvanica, Michx. (Wild Pink.) Viscid-pubescent: stems few or many, 6–9 inches high, from a strong tap-root: leaves mostly at the base, spatulate or oblanceolate, usually acutish at the apex, tapering below to long ciliated petioles; the two or three pairs of cauline leaves much shorter, lanceolate or narrowly oblong, acute: cymes small, terminal, dense, rarely more open: calyx clavate, purplish; the teeth short: petals white or pink, appendaged; the blade obovate, erose, 4–6 lines in length: the ovary long-stiped. — Fl. i. 272; Bot. Reg. iii. t. 247; Hook. Fl. Bor.-Am. i. 90; Gray, Gen. ii. 42, t. 115. *S. cheiranthoides*, Poir. Dict. vii. 176. *S. incarnata*, Lodd. Cab. t. 41. *S. platypetala*, Otth in DC. Prodr. i. 383. *Melandryum Pennsylvanicum*, Rohrb. l. c. 233, & Linnæa, xxxvi. 251. *S. Caroliniana*, Walt. Car. 142, with scarlet or crimson petals, and *S. rubicunda*, Dietr. Allg. Gartenzeit. iii. 196, with divided petals, are doubtful synonyms. — Open rocky woods, E. New England to S. Carolina and Kentucky.

= = Flowers crimson or scarlet, large.

S. Virginica, L. (Fire Pink, Catchfly.) Viscid-pubescent: stem striate, single, simple, 1–2 feet high: leaves spatulate or oblanceolate; the lower ones narrowed to ciliate-fringed petioles; the upper

lanceolate, sessile: flowers very large, an inch or more in diameter, loosely cymose; the central ones commonly nodding or reflexed after anthesis: calyx clavate or oblong, 8 lines in length, becoming obovate in fruit: petals crimson; the blade broadly lanceolate, 2- (rarely 4-) toothed at the apex. — Spec. 419 in part, not Willd.; Bot. Mag. t. 3342; Torr. & Gray, Fl. i. 192; Chapm. Fl. 51. *S. Catesbæi*, Walt. Car. 142. *S. coccinea*, Moench, Meth. Suppl. 306. — Common in open woods, on rocky hills, W. New York, S. W. Ontario (acc. to *Macoun*) to Minnesota (acc. to *Upham*), southward to Georgia and Arkansas.

S. rotundifolia, NUTT. (ROUND-LEAVED CATCHFLY.) Viscid-pubescent: stems weak, decumbent, branched: leaves rather large, varying from broadly lanceolate to subrotund, rather abruptly pointed; the lower ones contracted at the base to winged petioles: flowers large, showy, scattered or in loose cymes: calyx tubular, 10–13 lines in length, abrupt at the base, becoming clavate but not obovate in fruit: petals bright scarlet; the blade 8 lines in length, deeply bifid; the lobes more or less toothed: seeds smaller, smoother, and darker colored than in the preceding. — Gen. i. 288; Otth in DC. Prodr. i. 383; Torr. & Gray, Fl. i. 192. *Melandryum rotundifolium*, Rohrb. Monog. Sil. 234, & Linnæa, xxxvi. 257; Wats. Bot. King Exp. 431. — S. Ohio (acc. to Nuttall), Kentucky, and Tennessee, June to August.

S. regia, SIMS. (ROYAL CATCHFLY.) Viscid-glandular above, finely pulverulent-pubescent below: stems tall, erect, rather rigid, simple or sparingly branched, leafy: leaves ovate, acuminate, 3–7-nerved from the rounded sessile base; the lowest more or less contracted below: flowers showy, in a narrow oblong panicle: calyx cylindrical, 10–12 lines long, becoming somewhat spindle-shaped in fruit: petals spatulate-lanceolate, subentire, scarlet. — Bot. Mag. t. 1724; Sweet's Brit. Fl. Gard. new ser. t. 313; Torr. & Gray, Fl. i. 193. *S. Virginica*, form, Michx. Fl. i. 272. *Melandryum regium*, A. Br. Flora, 1843, 372; Rohrb. Linnæa, xxxvi. 250. — Prairies, Ohio to Alabama and westward to Missouri, not abundant.

+ + Rocky Mountain and Pacific species.

→ Flowers large, rather few, scattered: calyx cylindrical or clavate in anthesis, 8–12 lines long: corolla (except in *S. Parishii*) usually more than 10 lines in breadth; petals 4–∞-cleft, very rarely bifid: stems leafy.

= Seed-coat more or less roughened but firm.

a. Corolla deep red.

S. laciniata, CAV. Finely pubescent: root narrowly fusiform: stems erect or decumbent, somewhat rigid, knotty below; the branches

ascending: leaves lanceolate to narrowly linear, scabrous, ciliolate, narrowed to a sessile base: flowers terminal on the branches: calyx subcylindric or clavate even in fruit, 10 lines in length: petals bright scarlet, 4-cleft or very rarely bifid: capsule oblong scarcely at all ovate, commonly exserted at maturity. — Icon. vi. 44, t. 564; Lindl. Bot. Reg. xvii. t. 1444; Gray, Pl. Wright. ii. 17; Wats. Proc. Am. Acad. x. 341. *S. pulchra*, Torr. & Gray, Fl. i. 675 in part. *S. speciosa*, Paxt. Mag. of Bot. x. 219. *S. simulans*, Greene, Pitt. i. 63. *Lychnis pulchra*, Cham. & Schlecht. Linnæa, v. 234.— Central California to New Mexico. (Mex.)

Var. **Greggii**, Wats. Leaves oblong-lanceolate to ovate, otherwise not differing essentially from the type. — Proc. Am. Acad. x. 341, & Bibl. Index, 108. *S. Greggii*, Gray, Pl. Wright. ii. 17. *Melandryum laciniatum*, var. *Greggii*, Rohrb. Monog. Sil. 232. *Melandryum Greggii*, Rohrb. Linnæa, xxxvi. 256. — New Mexico, *Wright*, *Thurber*, *Matthews*; Arizona, *Buckminster*, *Lemmon*. (Mex., *Gregg*.)

S. Californica, Durand. Root simple, strong, penetrating vertically to a depth of 2–3 feet: stems several, procumbent or suberect, leafy: leaves lanceolate or ovate elliptic, more or less narrowed to the base, acuminate, rarely obtusish: corolla more than an inch broad; petals variously cleft, most commonly with two broad lobes flanked by two narrower ones: capsule ovoid, concealed until dehiscence by the rather broad calyx. — Pl. Pratt. 83; Brew. & Wats. Bot. Calif. i. 64. *S. pulchra*, Torr. & Gray, Fl. i. 675 in part. *S. Virginica*, Benth. Pl. Hartw. 299. *S. laciniata*, var. *Californica*, Gray, Proc. Bost. Soc. vii. 146; Wats. Proc. Am. Acad. x. 341. *S. Tilingi*, Regel, Act. Hort. Petrop. i. 99. *Melandryum Californicum*, Rohrb. Linnæa, xxxvi. 252. — Coast Mts. of Currie Co., Oregon (*Howell*), southward through N. and Central California to Ft. Tejon (*Xanthus*), and perhaps farther. Subject to much variation in foliage, the following being perhaps the best marked of the varieties.

Var. **subcordata**. Leaves ovate, suborbicular, shortly acuminate, closely sessile by subcordate bases. — Blue Cañon, *Kellogg* (1870), *Brandegee* (1888).

b. Corolla white or nearly so.

S. Wrightii, Gray. Very glutinous: rootstock thick, ligneous: stems several, ascending, a foot or more in length, branching, leafy: leaves lanceolate, acuminate, 1½–2 inches long, sessile; the lower attenuate below: calyx teeth filiform-attenuate, nearly half as long as the tube: petals white, 4-cleft; the lobes somewhat toothed: capsule on a stipe of nearly its own length. — Pl. Wright. ii. 17; Wats. Bibl.

Index, 110. *Melandryum Wrightii*, Rohrb. Linnæa, xxxvi. 253; Wats. Bot. King Exp. 431. — Mountain sides near the copper mines, New Mexico, *Wright* (862).

S. **Hookeri**, Nutt. Covered above with a fine grayish pubescence: root single, stout: stems several, short, slender, decumbent: leaves oblanceolate, rather numerous and approximate, 2–3 inches in length, acute or obtusish: flowers very large: calyx teeth acute, but not filiform: petals 4-cleft, white or pink. — Nutt. in Torr. & Gray, Fl. i. 193; Bot. Mag. t. 6051; Fl. d. Serres, t. 2093; Wats. Proc. Am. Acad. x. 341; Brew. & Wats. l. c. i. 64. *S. Bolanderi*, Gray, Proc. Am. Acad. vii. 330, & viii. 378; Bolander, Cat. 6. *Melandryum Hookeri*, and *M. Bolanderi*, Rohrb. l. c.; Wats. Bot. King Exp. 431. — Woodlands, W. Oregon and N. W. California.

= = Seed-coat vesicularly roughened, or crested.

S. **Parishii**, Wats. Grayish pubescent: root simple, thick, with a branching rootstock: stems several, decumbent, a span long: leaves lanceolate, acuminate, sessile, 1–2 inches long; the lower oblanceolate: flowers aggregated at the ends of the branches: calyx tubular, narrowed below, an inch long, with narrow subulate teeth 3–4 lines in length: petals narrow, scarcely exserted from the calyx, cleft into 4 or more filiform segments: seeds doubly crested with short vesicular hairs. — Proc. Am. Acad. xvii. 366. — San Bernardino Mts., California, *S. B. & W. F. Parish*.

+- +- Flowers smaller, not ordinarily exceeding 6–8 lines in diameter.

= Flowers borne in the forks of the branches forming a leafy inflorescence: calyx oblong or campanulate: leaves lanceolate or ovate.

S. **campanulata**, Wats. Finely glandular-pubescent: root thick, simple: rootstock branching, somewhat woody: stem slender, erect, leafy: leaves sessile, lanceolate: flowers on short deflexed peduncles: calyx green, broadly campanulate, reticulate-veined, toothed nearly to the middle: petals narrow; the limb cleft into 4 or more flesh-colored segments: capsule globular, 3–4 lines in diameter. — Proc. Am. Acad. x. 341; Brew. & Wats. l. c. i. 63. — Mountainous districts of N. California and S. Oregon.

Var. (?) Greenei, Wats. ined. More pubescent throughout: leaves ovate: petals greenish white. — Yreka, Calif., *Greene*; Cañonville and Wolf Creek, Oregon, *Howell Brothers*; Ashland, Oregon, *Henderson*. Apparently the commoner form.

S. **Menziesii**, Hook. Finely glandular-pubescent: stems weak, leafy, dichotomously branched above, 6 inches to a foot or more in

height: leaves ovate-lanceolate, acuminate at each end, thin: flowers very small: calyx obconical, obovate, or oblong, only 2½–4 lines in length: petals white, 2-cleft, commonly but not always unappendaged: capsule 1½–2 lines in diameter. — Fl. Bor.-Am. i. 90, t. 30; Torr. & Gray, Fl. i. 193 & 676; Rohrb. Monog. Sil. 147. *S. stellarioides*, Nutt. in Torr. & Gray l. c. i. 193. *S. Dorrii*, Kellogg, Proc. Calif. Acad. iii. 44, f. 12. — From Colorado to Vancouver Isl., S. California, and New Mexico.

= = **Flowers few, rather small, white or nearly so, nodding, borne in a lax naked panicle: petals cleft into four or more narrowly linear, almost filiform segments: styles long-exserted: leaves small, lanceolate, chiefly clustered upon the more or less cespitose base.**

S. longistylis, Engelm. Hoary-pubescent, minutely glandular above: root single: rootstock branched: stems 2–several, slender, 6–12 inches high, bearing 3–6 loosely paniculate or subracemose heads: leaves linear-lanceolate or oblanceolate, acute: calyx soon becoming ovoid: petals with a spatulate very pubescent, scarcely or not at all auriculate claw; the blade divided into 4 linear filiform segments; appendages linear, entire: capsule subsessile: seeds (apparently mature) small, dark red. — Engelm. in herb. Wats. Proc. Am. Acad. xxii. 469. — Scott's Mts., N. California, *Engelmann;* Ashland Butte, S. W. Oregon, *Henderson;* specimens collected in Plumas Co., Cal. (*Mrs. Austin*), and Mariposa Co. (*Congdon*), probably belong here also.

S. Lemmoni, Wats. Similar in habit: leaves broader, lanceolate, quite smooth or somewhat pubescent and glandular: calyx inclined to be herbaceous, especially the lanceolate acutish teeth, but the veins from the different nerves seldom anastomosing with each other: petals with a rather broad villous auriculate claw; the four divisions of the blade linear but not filiform: capsule nearly sessile: seeds red, somewhat irregular in shape, 1 line in length. — Proc. Am. Acad. x. 342; Brew. & Wats. l. c. i. 64. — California, Sierra Co., *Lemmon;* Janesville, *Brandegee;* Mariposa Co., *Congdon;* Coast Mts. north of San Francisco, *Rattan*. This species is too near the preceding and following, and it is not unlikely that more abundant material may show intergradation between them.

S. Palmeri, Wats. Similar in habit, more or less pubescent throughout, finely glandular above: leaves oblanceolate: calyx teeth commonly short and blunt, scarcely herbaceous; the base of the calyx often contracted about the short but distinct stipe of the ovary: the petals purplish; the claw villous, narrowly or broadly spatulate but

not auriculate; the limb deeply 4-cleft; the segments entire or bifid: seeds large for the genus, tuberculate, ash-colored at maturity. — Proc. Am. Acad. xi. 124; Brew. & Wats. l. c. i. 65. — S. California, Cucamaca Mts., *Palmer;* San Bernardino Mts., *Parish;* San Rafael Mts., *Ford.*

= = = Inflorescence as in the preceding: petals 2-cleft into linear segments: styles very long, the exserted portion as long as the calyx.

S. Bridgesii, ROHRB. Pubescent and viscid: stems leafy, usually simple up to the inflorescence, a foot or more in height: leaves sessile, lanceolate, acute, 1½–2 inches long: flowers slender-pedicelled, verticillately racemose or somewhat paniculate, nodding: calyx narrowly oblong or clavate in anthesis, broadly obovate in fruit; the teeth acute; the principal nerves broad, green; the commissural much narrower, seldom anastomosing with the others: petals ½–¾ inch long, considerably exserted, white or purplish: seeds very large, finely tuberculate, red. — App. Ind. Sem. Berol. 1867, 5, & Monog. Sil. 204; Wats. Proc. Am. Acad. x. 342; Brew. & Wats. l. c. i. 66. *S. incompta*, Gray, Proc. Am. Acad. vii. 330 = *S. Engelmanni*, Rohrb. Linnæa, xxxvi. 264, is a form of the same species, differing from the type only in the somewhat broader lobes of the petals and in the obtuse appendages. — Yosemite Valley, *Bridges, Gray;* Mt. Bullion, *Bolander;* Danah, *Congdon.* A closely similar if not identical plant has been found by *Rattan* on the Klamath River in N. California.

= = = = Flowers scattered, or variously paniculate: styles included or somewhat exserted, but not so long as in the preceding.

a. Fruiting calyx ovate, not contracted below, filled and distended by the subsessile capsule.

S. Thurberi, WATS. Densely grayish-pubescent and glandular: stems erect, 2 feet high, somewhat rigid, with ascending branches: leaves lanceolate, acute, contracted below, sessile, 2–4 inches long: flowers small, rather numerous: calyx cylindric becoming narrowly ovate, green-and-white striped, densely pubescent; the teeth slender with fimbriate laciniate margin: petals white, little exceeding the calyx; the claw rather broad with upwardly produced auricles; blade bifid with short oblong lobes, each with a small lateral tooth; appendages oblong, obtuse: capsule narrowly ovoid, scarcely stiped: seeds tuberculate and distinctly crested. — Proc. Am. Acad. x. 343. *S. plicata*, Wats. l. c. xvii. 366. — Near Janos, S. W. New Mexico, *Thurber;* peak south of Rucker Valley, *Lemmon.* (Mexico, *Pringle.*)

S. pectinata, WATS. Stems several, erect, 1½–2½ feet high: leaves lanceolate or oblanceolate, acute or acuminate; the lower long, tapering into winged petioles; the upper more or less reduced: flowers

purplish rose-colored, 6–8 lines broad: calyx becoming ovate in fruit: the teeth lance-linear to filiform, elongated, usually exceeding the mature capsule: petals with a narrow claw destitute of auricles; the blade obovate, bifid; the lobes rounded; the appendages lanceolate, entire: capsule large, ovate. — Proc. Am. Acad. x. 344; Brew. & Wats. Bot. Calif. i. 65. — Plumas Co., Calif., *Mrs. Ames;* Sierra Co., *Lemmon;* Carson City, Nev., *Anderson.* The typical form is very viscid glandular and somewhat branched.

Var. **subnuda.** Scarcely viscid: stems subsimple: radical leaves almost smooth, the cauline much reduced. — Near Empire City and at Franktown, Nev., *M. E. Jones.*

b. Capsule distinctly stiped: calyx relatively narrow, cylindric or in fruit clavate or obovate and usually rather distinctly contracted about the stipe of the capsule.

1. Petals 4 (–∝)-fid.

S. **Oregana,** Wats. Finely pubescent and very viscid, fetid: stems 1–several, erect, simple up to the racemiform or rather densely cymose-paniculate inflorescence: the lower leaves oblanceolate, narrowed below to long petioles; the upper leaves lanceolate or lance-linear, sessile: petals white with spatulate claws, glabrous, distinctly auricled at the summit; the blade 2–3 lines long, variously cleft into 4–6 or more linear segments: the stipe of the ovoid capsule about 2 lines long. — Proc. Am. Acad. x. 343; Brew. & Wats. l. c. i. 65. — Mountains of Oregon, Washington, and Montana, April to August.

S. **montana,** Wats. Finely pubescent: stems erect from a more or less decumbent base, 4–14 inches high: leaves lance-linear or narrowly oblanceolate, acuminate, 1–2½ inches in length; the cauline 3–4 pairs: inflorescence varying from subspicate to paniculate; flowers rarely solitary: calyx 6–9 lines in length: petals greenish white to rose-colored, exserted 2–4 lines: ovary long-stiped: capsule acutish. — Proc. Am. Acad. x. 343. — Near Carson City, Nev., *Anderson;* Sierra Co., Cal., *Lemmon.* *S. Shockleyi,* Wats. l. c. xxv. 127, from the White Mts., Mono Co., Cal., is apparently only a high-mountain form of the same species.

Var. **rigidula.** Stems simple, a span high, slightly rigid: leaves short, less than an inch in length, thickish and stiff: flowers white, subspicate. — Franktown, Nev., *M. E. Jones,* 1882.

S. **occidentalis,** Wats. Viscid-glandular, 2 feet high: stems one or two from a single strong root, branched above: leaves lanceolate or oblanceolate, 2–3 inches long: flowers in a very loose open panicle: calyx elongated, cylindric becoming clavate in fruit: petals purple,

4-cleft into lanceolate segments; the blade narrowed gradually into the cuneate claw, the latter devoid of auricles; appendages linear: capsule oblong, upon a stipe 2 lines in length. — Proc. Am. Acad. x. 343; Brew. & Wats. l. c. i. 64. — Calif., *Bolander*, without special locality; Plumas Co., Calif., *Lemmon*, *Mrs. Austin;* Butte Co., *Mrs. Bidwell.*

2. Petals bifid, each lobe sometimes bearing a very small lateral tooth.

S. purpurata, GREENE. "Stems numerous, from slender running rootstocks, 6–18 inches high, rather slender: whole plant pubescent and slightly viscid: leaves rather remote, linear-lanceolate, acute, 1½ inches long: flowers in terminal and subterminal peduncled or subsessile cymes of about 3: calyx purple, rugose-veiny, clavate, not inflated, ½ inch long or more; limb of petals more than half as long, white or pink, obcordate or bifid, appendaged at base." — This species, not seen by the author, appears to be near *S. Scouleri*, Hook. The description is drawn from Pittonia, ii. 229. — Porcupine River, interior of N. Alaska, *J. H. Turner.*

S. verecunda, WATS. Low, 6–12 inches in height, finely pubescent below, glandular-viscid above: stems several, leafy especially near the base: leaves narrowly lanceolate or oblanceolate to linear, acute: flowers rather few, mostly terminal or subterminal; the branches of the inflorescence erect: calyx soon becoming strongly obovate by the development of the broad ovoid capsule: calyx teeth with membranous ciliated margins: petals rose-colored; the claw glabrous, narrowly auricled; the blade 2-cleft into short entire oblong segments; appendages oblong, blunt and somewhat toothed at the apex. — Proc. Am. Acad. x. 344; Brew. & Wats. l. c. i. 65. *S. Engelmanni*, var. *Behrii*, Rohrb. Linnæa, xxxvi. 264. — Central California near the coast, Mission Dolores, San Francisco.

S. Luisana, WATS. Taller, finely pubescent: stems several from a branching caudex, erect, slender, viscid above: leaves narrowly oblanceolate to linear, acute, most numerous at the base; the cauline gradually reduced: flowers borne upon short spreading peduncles: fruiting calyx clavate; teeth long and narrow, with an incurved membranous ciliated margin: petals white, with narrowly auricled glabrous claw, and 2-cleft blade; segments linear-oblong, entire or with a small lateral tooth; appendages lanceolate, often toothed: capsule cylindric. — Proc. Am. Acad. xxiii. 261. — California, San Luis Obispo, *J. G. & S. A. Lemmon;* near Tolon, *Brandegee;* mountains south of Ft. Tejon, *Coville & Funston.*

S. platyota, WATS. Minutely pubescent throughout, glandular above: root thick: stems slender, 1½ feet high: leaves oblanceolate,

acute, narrowed below to winged ciliated petioles: inflorescence branched; flowers borne singly, or in the stronger individuals somewhat fascicled at the ends of the branches: calyx clavate in fruit, with broad green nerves; teeth acutish with membranous ciliated margins: mature capsule short, oblong, not exceeding 2 lines in diameter: the petals greenish white or roseate; claws villous toward the base, with broad entire or toothed auricles above; the blade bifid; the short oblong lobes with or without small lateral teeth; appendages lance-oblong. — Proc. Am. Acad. xvii. 366. — S. California, Cuyamaca Mts., *Palmer*, *Cleveland;* San Bernardino Mts., *Lemmon*, *Parish Bros.*, *Wright.* San Jacinto Mts., *Parish Bros.* (Lower Calif.) A very dwarf specimen apparently of this species from San Bernardino Mts., 11,000 ft. (*W. G. Wright*), has purplish petals and a calyx with blunter teeth and less prominent veins.

S. **Sargentii**, Wats. Cespitose, minutely pubescent: stems numerous, slender, erect, 6 inches high: leaves linear or nearly so, 1 to nearly 2 inches long, a line or so in breadth; the radical crowded, covering the rootstock with their slightly enlarged and imbricated bases; the cauline 2–3 pairs: calyx cylindrical, 7 lines long; teeth short: the petals white or pink; the claws exserted, with broad laciniately cleft auricles; the blade short, obovate, bifid; the segments each bearing a small lateral tooth: capsule well stiped, cylindrical, and very slender, at maturity scarcely more than a line in diameter: seeds tuberculate-crested, smooth on the faces. — Proc. Am. Acad. xiv. 290. — Table Mountain, Monitor Range, N. Nevada, *C. S. Sargent.*

c. Calyx broader, oblong, campanulate or rarely obovate, rather loosely surrounding the ovary, sometimes narrowed downward but not distinctly contracted about the carpophore.

1. Petals divided into 4 nearly equal segments: appendages fringe-toothed.

S. **Bernardina**, Wats. Covered with a fine grayish pubescence below, finely glandular above: caudex branching: stems several, slender, erect, 8–12 inches high, furrowed, 1–5-flowered: leaves grass-like, narrowly linear, 1-nerved, acute: terminal flower developing first, the lower ones borne upon branches 1½–2 inches long: buds acute: calyx green-nerved; the teeth lanceolate acutish, with membranous ciliated margin: petals white with rather short blade; the claw with broad laciniate auricles; appendages 4, long; the inner ones broad and toothed: capsule moderately stiped. — Proc. Am. Acad. xxiv. 82. — On shady slopes, Long Meadow, Tulare Co., Calif., *Palmer.*

2. Petals bifid; each segment with or without a smaller lateral tooth.
1* Low, 3–8 inches in height.

S. Grayii, Wats. — Cespitose, minutely pubescent and glandular: rootstock elongated, much branched: stem simple, erect, 4–6 inches high, 1–5-flowered; leaves short, oblanceolate or spatulate, slightly fleshy, 4–8 lines in length, the radical numerous, crowded; the cauline about 3 pairs: calyx broadly cylindrical: the teeth rounded; petals pink, with blade deeply bifid, and segments each bearing a lateral tooth; claw narrowly auricled: capsule short ovoid, scarcely stiped. — Proc. Am. Acad. xiv. 291; Robinson, Bot. Gaz. xvi. 44, t. 6. — Mt. Shasta above the timber line and near snow, *Brewer, Hooker & Gray, Packard, Pringle.* Specimens collected on Mt. Rainier by *E. C. Smith*, and having somewhat longer leaves, may be doubtfully referred to this species.

S. Watsoni. Finely glandular above, minutely pubescent, nearly smooth below: stems many, cespitose from a multicipital caudex, erect, very slender, simple, 4–8 inches in height, bearing 1–3 (rarely 5) flowers: leaves linear or very narrowly oblanceolate, acute, dark green; the radical numerous, an inch in length, seldom exceeding a line in breadth: the slender petioles expanding at the base, closely imbricated and connate by scarious membranes: calyx ovate or somewhat obovate, 5–6 lines in length, with purple more or less anastomosing nerves; the teeth with membranous margins: petals white or rose-colored: the blade short, a line in length, bifid; each segment usually bearing a short lateral tooth; appendages obtuse: styles ordinarily 3, rarely 4. — *Lychnis Californica*, Wats. Proc. Am. Acad. xii. 248. — California, near Ebbett's Pass, *Brewer*; Mt. Dana, *Bolander*; Sierra and Plumas Cos., *Lemmon.* As in *S. Lyallii*, the anthers are often infested by *Ustilago antherarum*, and in consequence enlarge and turn purple.

S. Suksdorfii, Robinson. Low, densely matted, alpine: stems 2–3 (rarely 4–5) inches high, simple 1–3-flowered, minutely pubescent below, glandular above: stem leaves about 2 pairs, linear, 3–7 lines long, a line wide; radical leaves numerous, crowded, similar or somewhat spatulate: calyx broadly cylindric or campanulate, seldom exceeding 5 lines in length; nerves conspicuous, simple below, anastomosing above: petals white, little exceeding the calyx, shallowly bifid; lobes entire; appendages oblong, retuse: stipe of capsule 1½ lines long. — Bot. Gaz. xvi. 44, t. 6. — California to Washington, Mt. Stanford, *Hooker & Gray*; Mt. Paddo, *Suksdorf*; Mt. Hood, *Howell*; Mt. Stewart, *Brandegee*; Mt. Rainier, *Piper.*

2* Taller.

S. Lyallii, Wats. Very finely puberulent or quite smooth: stems numerous from a much branched matted base, leafy: leaves thin, narrowly oblanceolate, acute, only 1–1¾ inches long, 2 lines broad: inflorescence considerably branched in the type: calyx varying with age from subturbinate to inflated campanulate, 4 lines long: petals dark purple, bifid with subentire lobes: anthers large, purple. — Proc. Am. Acad. x. 342. — Cascade Mts., Lat. 49°, *Lyall;* Sierra Co., Cal., *Lemmon;* Summit Camp, Cal., *Kellogg*. This doubtful species is to be distinguished from some forms of *S. Douglasii* only by its smaller flowers, more leafy habit, and darker petals. All the specimens at hand, including the type, are diseased and apparently sterile, the ovaries remaining undeveloped, and the anthers having been attacked by a fungus (*Ustilago antherarum*), to which their large size and dark color are probably due.

S. Douglasii, Hook. Finely pubescent, scarcely viscid: stems very slender, usually decumbent and geniculate at the base: leaves remote, long, linear to narrowly lance-linear, attenuate to each end, spreading, 2–3 lines long, 1–2 lines wide: flowers borne mostly in 3-flowered, long-peduncled cymes: calyx oblong or obovate, rather narrow at the base; the ends of the teeth surrounded by an ovate obtuse inflexed membrane: petals white or pink, 2-lobed; segments obtuse; claw moderately auricled; appendages oblong, obtuse: capsule narrowly cylindrical, 5 lines long; teeth recurved; stipe 1½ lines long. — Fl. Bor.-Am. i. 88; Torr. & Gray, Fl. i. 190; Wats. Bot. King Exp. 36, 431, & Proc. Am. Acad. x. 341; Brew. & Wats. Bot. Calif. i. 66. *Cucubalus Douglasii*, Eat. Man., ed. 7, 266. — Wahsatch Mts., Utah to Central California, northward to Montana and Brit. Columbia; June to September. A common and polymorphous species, of which the following are the chief varieties; all of them tending to intergrade with the type, and separated from it and each other by no constant or important floral character.

Var. multicaulis. Grayish-tomentulose and less glandular: the leaves more approximate, narrowly lanceolate or oblong, taper-pointed, erect: stems more rigid. — *S. multicaulis*, Nutt. in Torr. & Gray, Fl. i. 192. *S. Drummondii*, var. Torr. & Gray, Fl. i. 675. — "Oregon," *Nuttall;* Washington, Yakima Co., *Brandegee* (655 in part); Klickitat, *Howell;* Spokane Co., *Suksdorf, Ramm;* N. Idaho, *Spalding, Sandberg* (342); Montana, *Scribner, Canby.*

Var. Macounii. Minutely pubescent, somewhat glandular above: leaves distant, long and narrow, short-pointed, tapering very gradually

from near the apex to the base: calyx oblong, rather short, 4–5 lines in length, narrow, teeth purple-tipped: styles in specimens studied 3–4, very rarely 5. — *S. multicaulis*, Macoun, Cat. Canad. Pl. 494. *S. Macounii*, Wats. Proc. Am. Acad. xxvi. 124; Macoun, Bot. Gaz. xvi. 286. — Washington, *Lyall*, *Brandegee* (655 in part); British Columbia, summits of Rocky and Selkirk Mts., *Macoun*, *Dawson*.

Var. **macrocalyx**. Tall, puberulent or nearly smooth: leaves narrowly lanceolate or linear, attenuate both ways: calyx long, cylindrical, 7–8 lines in length. — Humboldt Mts., W. Nevada, *Watson*; Mt. Adams, Washington, *Suksdorf*, *Howell*.

Var. **viscida**. Glandular viscid, especially above: stems erect, rigid, mostly simple from a branched slightly woody base: calyx broadly oblong or almost campanulate, relatively short: leaves narrowly lanceolate to linear-oblong, thickish. — British Columbia, at Kicking Horse Pass, *Macoun*; Washington, Yakima Region, *Brandegee*; Olympic Mts., *Piper*.

Var. **brachycalyx**. Puberulent, not viscid; leaves distant, spreading, narrowly oblanceolate, attenuate: calyx short and broad, campanulate. — Oregon, Multnomah Co., 1877, *Howell*; also by same collector on Sauvie's Island, 1880.

Var. **monantha**. Nearly or quite smooth: stems very slender and weak, rising from a spreading much branched base: leaves thin, lanceolate or linear-oblong, and grass-like, narrowed both ways: flowers solitary, terminal, or 3–5 loosely cymose: calyx oblong-campanulate, inflated. — *S. monantha*, Wats. Proc. Am. Acad. x. 340; Brew. & Wats. l. c. i. 63. — Cascade Mts., Washington, *Harford & Dunn*; Webber Lake, Cal., *Lemmon*; N. Utah (?), *C. C. Parry*.

S. scaposa. Finely puberulent, somewhat viscid above: stem erect, subsimple, almost naked, 1–1½ feet high, rather rigid: radical leaves thickish, oblanceolate, acute, 3-nerved, somewhat glaucous, 2–3 inches in length, 3–5 lines broad; cauline leaves reduced to 1 or 2 pairs of distant bracts: inflorescence a narrow rigid panicle: flowers small, erect: calyx oblong or elliptic in outline, with simple green nerves: petals white, scarcely exceeding the calyx; the blade short, retuse; the claw with somewhat saccate auricles; appendages short obtuse: ovary shortly stiped. — Oregon, Blue Mts., *R. D. Nevius*, 1874; Cold Camp (355) and Currant Creek, *Thos. Howell*, 1885, May.

= = = = = Inflorescence denser, subspicate, or forming an elongated thyrse: styles included or moderately exserted.

S. Hallii, Wats. Stems several, from a stout root, simple, densely glandular-pubescent, 6 inches to 1½ feet high: leaves oblanceolate,

acute, tapering to the base, the midrib prominent below: flowers verticillately spicate, nodding: calyx even in anthesis broad, oblong or campanulate becoming obovate, strongly marked with purple or green nerves; those at the commissures irregularly anastomosing with the others and frequently double; the teeth triangular, acute, with membranous incurved margins: petals purple, not greatly exceeding the calyx; the claw very broad, laterally ciliate; the blade short, bifid; segments somewhat oblique, often toothed: capsule ovate on a short stipe. — Proc. Am. Acad. xxi. 446. *S. Scouleri* of various authors, not of Hooker; thus Gray, Am. Journ. of Sci. ser. 2, xxxiii. 405, & Proc. Philad. Acad. 1863, 58; Porter & Coulter, Fl. of Col. 12; Wats. l. c. x. 342 in part; Coulter, Man. of Rocky Mountain Bot. 32 in part. — Alpine regions of Colorado, *Hall & Harbour*, *Greene*, *French*, *Brandegee*, *Patterson*; a doubtful specimen from Arizona, *Knowlton*. August and September.

S. Scouleri, Hook. Pubescent, glandular-viscid above: root stout: stems simple, $1\frac{1}{4}$–$2\frac{1}{2}$ feet high: leaves narrowly oblanceolate or lance-linear, acuminate, not at all warty: inflorescence 6–8 inches long, verticillately spicate, or the lower flowers borne upon short appressed cymes: calyx clavate; nerves definite, but anastomosing above; teeth short with a broad membranous margin, ciliate: petals white or purplish; the claw with rather narrow, slightly laciniate auricles; the blade bifid; segments emarginate or toothed; appendages blunt: stipe of capsule 2 lines long. — Fl. Bor.-Am. i. 88; Torr. & Gray, Fl. i. 191; Rohrb. Monog. Sil. 213. *S. Drummondii*, Gray, Proc. Am. Acad. viii. 377. *Elisanthe Scouleri*, Ruprecht, Fl. Cauc. i. 200. — Frequent in mountainous districts of Oregon and Idaho to Vancouver Isl. and "Northwest Coast," *Menzies*; Colorado, *Brandegee*. July and August.

S. Pringlei, Wats. Habit, inflorescence, and calyx of the last: leaves very long, usually narrow and attenuate, both surfaces roughened, especially in the older leaves, with fine warts: petals purplish, bifid; segments each bearing a lateral tooth; auricles rather broad; appendages saccate: capsule ovate-oblong, well stiped. — Proc. Am. Acad. xxiii. 269. — Mt. Graham, Arizona, *Rothrock*; New Mexico, *Greene*. (Chihuahua, *Pringle*.)

S. Spaldingii, Wats. Viscid-tomentose: stems several, knotty, a foot high, very leafy: branches appressed or ascending: leaves lanceolate, sessile, $1\frac{1}{2}$–2 inches long: flowers subspicate or appressed cymose-paniculate: calyx in fruit obconical, more herbaceous than usual in the genus, net-veined nearly to the base; teeth rather large, triangular-lanceolate, acutish: the petals greenish white, not exceeding

the calyx; the claw broadly auricled; the blade bifid, very short indeed, scarcely surpassing the four small appendages: capsule ovate-oblong, moderately stiped. — Proc. Am. Acad. x. 344. — On the Clear Water, Central Idaho, *Spalding;* on the Lumnaha, Union Co., Oregon, *Cusick.* September.

6. LYCHNIS, Tourn. COCKLE. (Name ancient, from λύχνος, a lamp, in reference to the bright color of certain European species.) — Herbs, chiefly of Europe and Asia, much resembling various species of *Silene,* and sometimes distinguished only by the number of the carpels. — The latter being in a few cases variable, the separation of the two genera is rather arbitrary. The indigenous species are Western or Arctic (*L. alpina* extends eastward and southward to Lower Canada), but several introduced European species have become more or less common in the Atlantic and Middle States, and in Canada. — Inst. i. 333, t. 175; DC. Prodr. i. 385; Torr. & Gray, Fl. i. 194; Endl. Gen. 972–974; A. Braun, Flora, 1843, 369; Reichb. Icon. Fl. Germ. vi. t. 303–308; Benth. & Hook. Gen. i. 147; Wats. Proc. Am. Acad. xii. 246; Baill. Hist. des Pl. ix. 108; Pax in Engl. & Prantl, Nat. Pflanzenfam. iii. 1 b. 72.

§ 1. Teeth of the usually more or less inflated calyx not twisted: ovary unicellular at the base: capsule with its five valves normally bifid, but sometimes indistinctly so or entire. (MELANDRIUM, Röhl., Deutschl. Fl. 254, and EULYCHNIS, Fenzl in Endl. l. c. 974. The separation of these sections in the American species is not practicable, as the inflation of the calyx and toothing of the capsule are not sufficiently definite or constant characters.)

* Native species, Western or Arctic: leaves narrowly lanceolate, spatulate or linear; the radical usually numerous and the cauline few.

+ Tall: stems erect, usually a foot or more in height, several to many flowered: species ranging from Winnipeg to the Sierras, but chiefly of the Rocky Mountains, though not truly alpine.

= Capsule sessile: petals included or scarcely exserted.

L. Drummondii, WATS. Finely grayish-pubescent throughout, often purple-glandular above: stems erect, simple, somewhat rigid: leaves narrow; the lower oblanceolate; the upper lance-linear: flowers on long usually appressed pedicels: calyx in the typical form oblong-cylindric or scarcely ovate, with green nerves: petals small, white or purplish, with the short bifid minutely appendaged blade narrower than the claw: seeds uniformly tubercled, not distinctly crested. — Bot. King Exp. 37, 432, & Proc. Am. Acad. xii. 248. *L. apetala,* Gray, Am. Journ. Sci. ser. 2, xxxiii. 405 in part. *L. apetala,* var.

pauciflora, Porter in Hayden, Rep. 1870, 473. *Silene Drummondii*, Hook. Fl. Bor.-Am. i. 89; Torr. & Gray, Fl. i. 191 in part; Rohrb. Monog. Sil. i. 83. *Elisanthe Drummondii*, Rupr. Fl. Cauc. i. 200. — Fort Vancouver to Winnipeg valley and southward along the Rocky Mts. to N. Mexico and Arizona; flowering through the summer; very variable, especially in pubescence. A lanate form has been found by Bourgeau in the Winnipeg valley; a form distinguished by its broader thinnish leaves, purple glandular pubescence, and more distinctly ovate calyx, has been collected in the Uintas, *Watson*, and at Gray's Peak, *Hooker & Gray*, *Patterson*.

= = Capsule more or less distinctly stiped: petals conspicuously exserted.

L. elata, Wats. Finely grayish-pubescent: stems erect, simple: leaves lanceolate or linear-oblong; the radical spatulate, 3–4 inches in length: flowers nodding on short spreading pedicels: calyx membranaceous, inflated, oblong, with rather short triangular teeth: petals purplish, exserted 4-5 lines from the calyx-tube; the blade bifid, each segment bearing a short narrow lateral tooth; the claw distinctly and rather broadly auricled: stipe of the capsule over a line in length. — Proc. Am. Acad. xii. 249. *Silene Scouleri*, Gray, Am. Journ. Sci. ser. 2, xxxiii. 405. — Rocky Mts., British America, *Bourgeau*; Colorado, *Parry*, *Miss Eastwood*, *Letterman*. This species much resembles *Silene Hallii*, except in the number of styles. Careful observations upon the constancy or variability of this character are greatly to be desired.

L. Parryi, Wats. Viscid-glandular: stems several, nearly naked, scarcely a foot in height: leaves linear, 1–2 inches in length: flowers erect or nodding on rather short pedicels: calyx oblong or obovate, inflated, purple-nerved: petals exserted 2–3 lines, the blade short, bifid, and with lateral teeth; the claw as in the preceding; appendages broad and blunt; stipe of the capsule about a line in length. — Proc. Am. Acad. xii. 248. — Northwestern Wyoming, *Parry*. Styles sometimes 4.

L. nuda, Wats. Finely pubescent, slightly viscid: stems erect, slender, bearing but 2–3 rather remote pairs of short linear leaves: radical leaves oblanceolate, acute, attenuated below to long slender petioles: flowers few, the lower on branches 2–3 inches long: calyx somewhat firmer than in the two preceding, not at all inflated, at first rather narrowly oblong, becoming obovate in fruit: petals white or rose-colored, 7–8 lines long; the blade bifid; the segments again 2-cleft; the claw broadly auricled, less attenuate to the base than in the

preceding: capsule ovate, 5-toothed, very shortly stiped. — Bot. King Exp. 37, & Proc. Am. Acad. xii. 248. — E. Humboldt Mts., Nevada, 9,000 ft., *Watson*.

← ← Alpine or far Northern species.

→ Calyx ovate, not strongly inflated: flowers on each stem 3 or 5 densely aggregated, rarely solitary: petals exserted: seeds tuberculate.

L. triflora, R. Br. Viscid-tomentose: stems 3–8 inches high: leaves thickish, linear-oblong, often conspicuously ciliate: flowers short-pedicelled: calyx with 10 broad indistinct purple or green nerves: petals white or roseate; the blade obcordate; the claw scarcely auricled. — Ross Voy. App. cxlii., name only; Sommerfelt, Mag. Naturv. ii. (1824), 151, 152; Wats. l. c. 247. *L. apetela*, var. *pauciflora*, Dur. Pl. Kane, 189. *Agrostemma triflora*, Don, Syst. i. 417. *Melandrium triflorum*, Liebm. Fl. Dan. xiv. t. 2356; Rohrb. Linnæa, xxxvi. 231. *Wahlbergella triflora*, Fries, Summa Scand. 155. — Greenland, from Polaris Bay (*Bessel*) southward; Grinnell Land, *Greely*.

Var. Dawsoni. Calyx with principal nerves double or triple, joined by interlacing veinlets; the intermediate nerves beneath the sinuses inconspicuous or wanting: petals very narrow; the blade oblong, bifid, hardly to be distinguished from the narrow claw. — Gravel banks, N. British Columbia, 100 miles northeast of Dease Lake, *Dr. G. M. Dawson*.

→ → Calyx ovate, scarcely inflated: flowers erect or slightly nodding in anthesis: stems usually 1-flowered, occasionally loosely several-flowered.

= Rocky Mountain and Western alpine species.

L. Kingii, Wats. Densely covered with a very short pubescence, somewhat glandular above: stems slender, erect, 4–6 inches high, 1–2-flowered: leaves narrowly linear: the blade of the petals rather short and broad, emarginate; the claw with broad ciliated auricles; appendages oblong: filaments pubescent. — Proc. Am. Acad. xii. 247, exclusive of Wyoming plant. *L. Ajanensis?* Wats. Bot. King Exp. 37. — Peaks of the Uintas, N. Utah, *Watson*. Additional material of this little known species may perhaps show it to be merely a Southern form of *L. affinis*.

L. montana, Wats. Glandular-pubescent: root thickish, subsimple: stems erect, 2–4 inches high: leaves linear, 1–1½ inches in length: calyx green- or rarely purple-nerved, 5–6 lines long; the teeth short, scarcely acute: petals narrow, about equalling or a line or two exceeding the calyx; the blade small, bifid; the claw narrow, ½–¾ lines in breadth; appendages small or absent: filaments naked: capsule sessile or nearly so. — Proc. Am. Acad. xii. 247, excl. of

specimens from the Uintas. *L. apetala*, Gray, Am. Journ. Sci. ser. 2, xxxviii. 405, & Proc. Acad. Philad. 1863, 58 in part. *L. Kingii*, var. with naked filaments, Wats. l. c. 247. — Mountains of Colorado, *Parry*, *Hall & Harbour*, *Scovill*, *Wolf;* N. W. Wyoming, *Parry*.

= = Arctic or sub-arctic species, or at least of the far North.

L. affinis, Vahl. Glandular-pubescent, 3–6 inches high: leaves oblanceolate-linear, ¾–3 inches in length: calyx ovate-elliptic, usually contracted at the mouth: petals white or pink; the blade narrow, entire or retuse, narrowed from near the end to the summit of the more or less distinctly auricled claw; appendages oblong. — Vahl in Fries, Mant. iii. 36 (1842). *L. triflora*, Hornem. Fl. Dan. xiii. t. 2173. *L. apetala*, Hook. f. Arct. Pl. 321 in part. *Melandrium affine*, Vahl in Liebm. Fl. Dan. xiv. 5, obs. *Wahlbergella affinis*, Fries, Summa Scand. 155. *Melandryum involucratum*, var. *affine*, Rohrb. Linnæa, xxxvi. 217. — Greenland to N. Alaska, *McLenegan*, and according to Rohrb. l. c. southward to Labrador. Warming in Vidensk. Selsk. Forhand. 1886, 129, states that in Norway the flowers are of two kinds, perfect and pistillate, and that the petals in the latter are devoid of appendages and auricles.

L. Tayloræ. Very slender, 1–1½ feet high, puberulent, nearly smooth below, glandular above: stem erect, bearing 3–4 pairs of leaves and two or three long slender almost filiform 1–3-flowered branches: leaves thin, lance-linear, acute or attenuate both ways, finely ciliate, and pubescent upon the single nerve beneath, otherwise glabrate, 2–2½ inches in length: flowers terminal or subterminal on the branches: calyx ovate, not much inflated, about 4 lines long, in anthesis but 2 lines in diameter, with green nerves interlacing above; the teeth obtuse, with broad green membranous ciliate margins: petals 1½ times the length of the calyx; the blade obcordate, 1¼ lines long, considerably broader than the slender narrowly auricled claw; appendages lance-oblong. — Peel's River, Mackenzie River delta, *Miss E. Taylor*, July, 1892. A fragmentary specimen collected on the Kowak River, N. Alaska, by *McLenegan*, may be doubtfully referred to this species.

+ + + Calyx large, much inflated, almost globose: flowers commonly pendulous in anthesis: seeds margined: stems one-flowered except in var. *elatior*.

L. apetala, L. More or less viscid-pubescent: stems 2–6 inches high: flowers perfect or pistillate, at first pendulous, but becoming erect in fruit: petals in the typical form included; the blade short, bifid; the segments rather irregular, sometimes with a small lateral lobe; the claw auricled. — Spec. 437. *L. frigida*, Schrank, Pflanz.

Lab. 25. *L. montana*, Wats. Proc. Am. Acad. xii. 247 (so far as the Utah specimens are concerned). *Agrostemma apetala*, Don, l. c. i. 416. *Melandryum apetalum*, Fenzl in Ledeb. Fl. Ross. i. 326.; Warming, Bot. Foren. Festskr. 1890, 251, f. 25; 26. *Wahlbergella apetala*, Fries, l. c. 155. — A polymorphous species, the forms of which have been elaborated by Regel in Radde's Reisen in Ost-Sib. i. 325–329. N. Greenland and Grinnell Land to Alaska and southward along the Rocky Mountains to Montana, *Canby*, and Uintas, N. Utah, *Watson.*

Var. glabra, REGEL. Glabrous throughout, otherwise as in the type. — Regel, l. c. 325 & 327. — Rocky Mts. of Brit. Amer., *Bourgeau;* St. Paul's Isl., Alaska, *Elliott;* Schmagin Isl., *Harrington*. The Alaskan form differs from Bourgeau's plant, upon which the variety was founded, in having much larger thinner leaves.

Var. elatior, REGEL (extended). Pubescent, taller, 6–12 inches in height: stems commonly several-flowered: petals sometimes considerably exserted. — Regel, l. c. 328, including var. *macropetala*, so far as the American specimens are concerned. — Kodiak Isl. and northward in Alaska to Kotzebue Sound, acc. to Regel.

* * European species, adventive in the Eastern and Middle States and in Canada: corolla much exserted.

+ Leaves usually large, cauline, lanceolate or ovate-lanceolate: flowers mostly diœcious: valves of the capsule distinctly 2-toothed.

L. DIURNA, Sibth. (RED LYCHNIS. RED CAMPION.) Calyx oblong, rather short, 4–6 lines long, reddish; the teeth triangular-lanceolate, acute: corolla red or pink (rarely white), expanding in the morning: capsule large, globose, with a wide mouth; the teeth recurved. — Fl. Oxon. 145; Reichb. l. c. vi. t. 304. *L. dioica*, var. *α*, Linn. Spec. 437 in part, and var. *a*, *rubra*, Weigel, Fl. Pom.-Rug. 85. *Melandrium silvestre*, Röhl. Deutschl. Fl. ed. 2, ii. 274. *M. rubrum*, Garcke, Fl. Deutschl. ed. 4, 55. — Not infrequent in Atlantic States.

L. ALBA, Mill. (EVENING LYCHNIS. WHITE CAMPION.) Calyx green, longer than in the preceding; the teeth lance-linear, attenuate: corolla more commonly white, opening in the evening: capsule ovate-conical; the teeth erect or slightly spreading. — Dict. ed. 8 (1768). *L. dioica*, var. *β*, Linn. Spec. 437. *L. vespertina*, Sibth. Fl. Oxon. 146 (1794). *Melandryum album*, Garcke, l. c. 55. — Ballast and waste lands, sometimes by roadsides and in cultivated fields, chiefly eastward.

+ + Leaves narrower: flowers perfect: valves of the capsule 5, entire.

L. FLOS-CUCULI, L. (RAGGED ROBIN.) A slender smoothish perennial, with a furrowed, sometimes minutely roughened stem, 1½–2 feet high: lower leaves oblanceolate; the upper lance-linear: calyx

oblong-ovate, equally 10-ribbed: flowers cymose-paniculate: petals pink or red, cleft to below the middle into 4 linear acute segments.— Spec. 436. *Coronaria Flos-cuculi*, A. Br. Flora, 1843, 368.— Moist fields, New Brunswick, New England, and New York.

§ 2. VISCARIA, Röhl. (as genus). Calyx not inflated; the teeth not twisted: ovary septate at the base: the teeth of the capsule as many as the styles.—Deutschl. Fl. ed. 2, ii. 37; Endl. Gen. 973.

L. alpina, L. Smooth, biennial or perennial, erect, 2 inches to a foot in height: leaves numerous, clustered at the base, linear or oblong, thickish; the cauline 2–4 pairs, erect or ascending: flowers small, the densely clustered cymes forming a terminal head: bracts conspicuous, membranaceous, tipped with red: calyx short-campanulate or turbinate, membranaceous, scarcely nerved; the teeth bright red: petals pink, bifid; segments linear.— Spec. 436; Torr. & Gray, Fl. i. 194; Reichb. Icon. Fl. Germ. vi. t. 307; Wats. l. c. 246. *Lychnis Suecica*, Lodd. Cab. 881.— Greenland to Labrador, and Mt. Albert, Quebec, *Allen*, *Macoun*. (Europe.)

§ 3. AGROSTEMMA, Fenzl. (CORONARIA § PSEUDAGROSTEMMA, A. Br.) Calyx teeth filiform, twisted: flowers few, large: petals with conspicuous awl-shaped appendages: teeth of the capsule as many as the styles: plant woolly.— Endl. Gen. 974.

L. CORONARIA, Desrousseaux. (MULLEIN PINK.) Covered with dense white wool throughout: stem 1½–3 feet high: leaves oval or oblong: calyx ovoid; the alternating ribs more prominent; the teeth small, much shorter than the tube: petals large, crimson.— Desr. in Lam. Dict. iii. 643. *Agrostemma Coronaria*, L. Spec. 436. *Coronaria tomentosa*, A. Br. Flora, 1843, 368.—A handsome plant, tending to escape from cultivation in several localities in New England and the Middle States. (Europe.)

7. AGROSTEMMA, L. CORN COCKLE. (Name from ἀγρός, field, and στέμμα, crown.)—A genus of two species, both natives of the Mediterranean region; one of them, growing in cultivated fields, now cosmopolitan, having been widely disseminated in grain seed.— Gen. n. 379; Pax, l. c. 70. *Githago*, Desf. Cat. Hort. Par. 266; Baill. Hist. des Pl. ix. 108. *Lychnis* § *Githago*, DC. Prodr. i. 387; Benth. & Hook. Gen. i. 148.— Although often united with *Lychnis*, these species through the different relative position of the carpels and petals seem to deserve rank as a separate genus, especially if *Sagina* is to be kept distinct from *Arenaria* upon the same ground.

A. GITHAGO, L. Annual or biennial, covered with a long, silky, appressed or spreading pubescence: stem 1½–3 feet high, somewhat

branched: flowers few, long-peduncled: leaves linear, acute, 2–4 inches in length: corolla 1–1½ inches in diameter; petals obovate, dark purplish red, somewhat lighter toward the claw, and with small black spots: calyx teeth usually an inch or more in length. — Spec. 435. *Lychnis Githago*, Scop. Fl. Carn. ed. 2, i. 310. *Githago segetum*, Desf. l. c. 266.

15. **DRYMARIA**, Willd. (Name from δρυμός, an oak copse; some species having been supposed to prefer that habitat.) — A group of low diffusely branched plants, chiefly of the New World; our species being weak annuals. — Willd. in Rœm. & Sch. Syst. v. p. xxxi; HBK. Nov. Gen. et Sp. vi. 21, t. 515, 516; DC. Prodr. i. 395; Wats. Bibl. Index, 102, & Proc. Am. Acad. xvii. 327–329.

* Cauline leaves rather broadly ovate.

D. Fendleri, Wats. An erect annual, 2–10 inches high: stems, peduncles, and petioles finely glandular-pubescent: leaves membranaceous, reniform-ovate, subcordate, abruptly acuminate, nearly smooth, 4–5 lines long, on slender petioles half their length: flowers aggregated in terminal fascicles, or single in the forks; sepals herbaceous, lanceolate, acuminate, 1–3-nerved. — Proc. Am. Acad. xvii. 328. *D. cordata*, Gray, Pl. Fendl. 13. *D. glandulosa*, Gray, Pl. Wright. ii. 18; Torr. Pacif. R. Rep. iv. 70, & Bot. Mex. Bound. 37. — New Mexico and Arizona.

D. holosteoides, Benth. Prostrate, smooth and somewhat glaucous: stems numerous, each bearing 2–3 remote fascicles of leaves and flowers: leaves appearing quaternate, ovate, obtuse, thickish, 3–5-nerved, 3–6 lines long, rather abruptly contracted into a slender petiole 2–3 lines in length: pedicels equalling or slightly exceeding the petioles, 1-flowered: sepals obtusish, 1¾ lines long, with conspicuous membranous margins: seeds black, hooked, or somewhat cocleate. — Bot. Sulph. 16; Wats. Bibl. Index, 103. — Dry bed of Tarlinga Creek, W. Texas, *Havard.* (Lower Calif.)

* * Cauline leaves linear, pseudoverticillate.

D. sperguloides, Gray. Covered with a fine grayish pubescence or quite glabrous: radical leaves spatulate, fugacious: stem erect, with spreading branches and pseudoverticels of 4–8 sessile narrow obtuse slightly fleshy leaves 5–10 lines long, ½ line in breadth: inflorescence diffuse; flowers pedicellate. — Pl. Fendl. 11, & Pl. Wright. ii. 19; Torr. Bot. Mex. Bound. 37. — Cornfields, etc., Texas, near Presidio del Norte, *Parry;* New Mexico, *Fendler*, *Wright;* Arizona, *Palmer*, *Lemmon.*

* * * Cauline leaves linear, opposite: stems erect, delicate, much branched · flowers short-pedicelled in the forks of a diffuse inflorescence.

D. effusa, Gray. Viscid, especially upon the upper part of each internode: radical leaves obovate, seldom persisting; cauline very narrowly linear, obtuse: sepals elliptic, obtuse, or scarcely acute, not distinctly ribbed, considerably exceeded by the petals. — Pl. Wright. ii. 19; Torr. Bot. Mex. Bound. 37. — Mountainous districts, New Mexico, *Wright; Arizona, Rothrock, Lemmon.* (Adjacent Mexico, *Thurber.*)

D. tenella, Gray. In size and habit closely resembling the preceding, but glabrous and not viscid: sepals acutish, rather strongly ribbed, a line in length, about equalling the petals. — Pl. Fendl. 12, & Pl. Wright. ii. 19. — Shady places, woodland, New Mexico, *Fendler, Wright, Greene.* (Adjacent Mexico, *Pringle.*) D. nodosa, Engelm., of Mexico, is a third closely related species, but has glandular stems, and somewhat larger flowers with attenuate rather rigid sepals 1½–2 lines long.

16. POLYCARPON, Lœfling (πολύς, much, many, and καρπός, fruit, from the innumerable capsules.) — A small genus of low, much-branched annuals. Flowers numerous, cymose, very small. — Genus ascribed to Lœfling in Linn. Gen. ed. 6, n. 105; DC. Prodr. iii. 376; Torr. & Gray, Fl. i. 173.

P. tetraphyllum, L. Nearly or quite smooth: stems 2–6 inches long, prostrate, or ascending: leaves quaternate or opposite, oblong or obovate, obtuse, 2½–6 lines long, abruptly narrowed to short petioles: stipules and bracts scarious, acuminate, the latter equalling the rather sharply acuminate sepals: petals white. — Spec. ed. 2, 131; Eng. Bot. t. 1031; Ell. Sk. i. 182. — Introduced in S. Carolina near Charleston and at Camden, *Curtis.* (Old World.)

P. depressum, Nutt. Smaller: stems numerous, 1–2 inches long: leaves opposite, spatulate, obtuse, attenuate to slender petioles: bracts much shorter than the scarcely carinate sepals: petals very narrow or subfiliform: capsule spherical. — Nutt. in Torr. & Gray, l. c. 174; Brew. & Wats. Bot. Calif. i. 71. — Sand hills near San Diego, *Nuttall, Cleveland;* near San Bernardino, *Lemmon.* (Lower Calif., *Orcutt, Palmer.*)

17. LŒFLINGIA, L. (Dedicated to Peter Lœfling, a Swedish traveller and naturalist, born 1729.) — Small spreading glandular somewhat rigid annuals, with subulate inconspicuous leaves, and sessile solitary or more commonly fasciculate greenish flowers. — Gen. ed. 6, n. 52; DC. Prodr. iii. 380.

* Outer sepals provided with lateral teeth.

L. Texana, Hook. Branching from near the base: branches 4–6 inches long: flowers chiefly borne upon short secund and somewhat recurved branchlets: sepals straight or slightly curved: stamens in the flowers examined 3 (5 according to Hook. and Gray): seeds rather broadly obovate. — Icon. t. 285 (text with t. 275). Brandegee, Zoe, i. 219. *L. squarrosa*, Torr. & Gray, Fl. i. 674; Gray, Gen. ii. 23, t. 106 (Figs. 7 and 8 represent the seed too narrow and with cotyledons incumbent instead of accumbent as is the case); Coult. Man. of S. W. Tex. 31. — Central and Eastern Texas, *Drummond*, *Wright*, *Hall;* differing slightly, but as it appears constantly, from the following.

L. squarrosa, Nutt. Smaller, 2–4 inches high: branchlets scarcely or not at all secund: sepals pretty strongly recurved and squarrose: stamens 3 (–5?): seeds oblong or elliptical in outline. — Torr. & Gray, Fl. i. 174; Brew. & Wats. Bot. Calif. i. 72; Wats. Bibl. Index, 104 (excl. syn.); Brandegee, l. c. 219. — Sandy soil, California, San Diego northward to Sierra Co., *Lemmon*.

* * Sepals all entire.

L. pusilla, Curran. Low and condensed, 2–3 inches in height; branches closely flowered, not distinctly secund: sepals lanceolate, acute and bristle-tipped: stamens (in flowers examined) 3. — Bull. Calif. Acad. i. 152; Brandegee, Zoe, i. 220. — Tehachapi, California, 4,000 ft., *Mrs. Curran*. — This very interesting species has the calyx of a *Cerdia*, but is distinguished from that genus by the number of stamens, the absence of a style, and the accumbent position of the cotyledons, which in *Cerdia* appear to be constantly incumbent.

18. STIPULICIDA, Michx. (Name from the Latin *stipula*, stalk, blade, stipule, and *cædere*, to cut, from its deeply divided stipules.) — A monotype, scarcely differing in its technical characters from the Old World *Polycarpæa*, but with a very distinct habit, somewhat that of an *Eryogonum*. — Fl. i. 26, t. 6; Gray, Gen. ii. 25, t. 107.

S. setacea, Michx. l. c. A span high: root simple: the stems dichotomously forked: radical leaves spatulate, 2–4 lines long, narrowed to a slender petiole: flowers small, fascicled at the ends of the naked branches. — Chapm. Fl. 47. *Polycarpon stipulicidum*, Pers. Syn. i. 111; Pursh, Fl. 90. — Sandy soil, North Carolina to Florida.

X.

CONTRIBUTIONS FROM THE CRYPTOGAMIC LABORATORY OF HARVARD UNIVERSITY.

XX. — NEW SPECIES OF LABOULBENIACEÆ FROM VARIOUS LOCALITIES.

By Roland Thaxter.

Presented May 10, 1893.

The present paper, which is the fourth preliminary contribution towards an illustrated monograph of the Laboulbeniaceæ now in preparation, is based upon material collected during the past year in Maine and Massachusetts, or derived from the collections of Coleoptera in the Museum of Comparative Zoölogy in Cambridge, for the privilege of examining which, as well as for numerous determinations of hosts, the writer is greatly indebted to Mr. Samuel Henshaw.

The additions to the family herewith presented serve nearly to double the number of forms previously known, and from the astonishing modifications which many of them exhibit form a very important contribution towards a knowledge of what must inevitably prove a large and varied group. Apart from mere singularity of form, however, the most interesting phenomenon which they illustrate is perhaps that connected with the not unexpected separation of the sexes upon distinct individuals, which occurs in two of the new genera described.

In the present as well as in the three previous papers above mentioned, the writer has purposely avoided any discussion of the many interesting questions connected with the general morphology of the group and the special development and relationships of the various forms described, since these matters, which will find their proper place in the monograph above referred to, could not well be considered in a series of purely descriptive papers. It has seemed, however, best in the following descriptions, to recognize the sexual character of the appendages peculiar to the group by discarding the term "pseudoparaphysis," hitherto used to designate them, and substituting

in its place the term "antheridial appendage," in recognition of their true character. In other respects the terms here used correspond with those previously employed, except that it has been found convenient to designate the blackened cell from which the appendages arise in typical species of Laboulbenia as the "insertion cell."

Of the fifty-two new species described, twenty are referred to the genus Laboulbenia, five each to Acanthomyces and Ceratomyces, two each to Heimatomyces and Corethromyces, and one each to Cantharomyces and Peyritschiella; while the remaining forms are included under new genera as follows: Haplomyces, having three species; Rhadinomyces and Amorphomyces, each with two species; Dichomyces, Chætomyces, Idiomyces, and Dimorphomyces, each including a single species.

DIMORPHOMYCES, nov. gen.

Sexual organs borne on separate individuals.

Male individual consisting of a series of several superposed cells, the sub-basal one bearing the large cellular long-necked antheridium.

Female individual consisting of several superposed cells, from the basal of which arise one to several perithecia and simple sterile appendages. Perithecia asymmetrical; spores indistinctly septate.

This and the succeeding genus appear certainly to present instances of genera characterized by an invariable separation of the sexes on distinct and peculiar individuals. In the present genus the antheridium, though resembling that of Amorphomyces in general shape and in the presence of a long neck for discharging the nearly spherical spermatia, is far more highly developed, being proportionately much larger and distinctly cellular near the base. The asci are produced basally from an indistinct ascogenic cell, and the usual septum is scarcely visible in the mature spores.

Dimorphomyces denticulatus, nov. sp.

Male individual. Receptacle consisting typically of five superposed cells, tapering and more or less suffused with brown distally, the terminal cell (when uninjured) ending in a nearly spherical blackish tip. Antheridium arising from the large sub-basal cell of the receptacle, its base inflated inwardly, composed of several cells surrounding a central canal connecting with the long brownish slightly curved neck. Total length to tip of receptacle 40 μ; to tip of antheridium 50–55 μ. Greatest width 14 μ.

Female individual. Receptacle consisting of three superposed cells, short, the distal cell cylindrical and symmetrically rounded at

the apex. From the basal cell which becomes broad, lobulated, and indistinctly vertically septate, arise directly one to four perithecia and one to four sterile, usually simple appendages, the latter tapering slightly, distinctly septate, hardly exceeding the mature perithecia in length. Perithecia slender, the base prolonged into a short slender stalk separated from the basal cell of the receptacle by a septum between which and the ascogenic cell no septa are visible: the apex broad, apiculate, sharply bent towards a tooth-like projection which arises just below it. Spores 33 × 3.5 μ. Perithecia 65–70 × 15 μ. Appendages about 110 μ. Receptacle about 40 μ long.

On abdomen of *Falagria dissecta* Er., Massachusetts.

AMORPHOMYCES, nov. gen.

Sexual organs borne on separate individuals.

Male individual. Receptacle consisting of two superposed cells bearing terminally a single one-celled long necked antheridium.

Female individual. Receptacle consisting of a few superposed cells, without true appendages, bearing terminally a single large perithecium. Asci arising from a lateral placenta-like ascogenic area.

The single antheridium seems constant in the species in which the male individual is known, but it is not improbable that further knowledge of the genus may necessitate a modification of the above diagnosis in this respect, since, as shown by other genera, the number of antheridia present is usually variable.

A third form, apparently referable to this genus, was observed on a species of Lathrobium, and is marked by a greater development of the lateral prominence from the receptacle present in *A. floridanus*.

Amorphomyces Falagriæ, nov. sp.

Male individual consisting of three superposed cells, the basal and sub-basal about equal, the latter suffused with dark brown; the distal cell an antheridium basally slightly inflated, distally prolonged into a cylindrical neck bent to one side. Total length 48 μ by 10 μ broad.

Female individual. Receptacle hyaline, consisting of a small basal cell, sometimes partly divided, surmounted by a few (three or four) small cells more or less irregular in shape, number, and position, from which arises the large pale brownish yellow perithecium, which is curved strongly on the side opposite the ascigerous area, and tapers to a blunt almost truncate tip furnished with rather prominent lips. Spores subcylindrical, about 37 × 6 μ. Perithecia 100 × 30–33 μ. Total length 130–138 μ.

On abdomen of *Falagria dissecta* Er., Massachusetts.

AMORPHOMYCES FLORIDANUS, nov. sp.

Male unknown.

Female. Receptacle consisting of a basal cell, partly divided, from which arises on one side (corresponding to the ascigerous side of the perithecium) a somewhat indurated projection which extends upwards nearly to the base of the perithecium. Perithecium externally rounded and tapering considerably to the blunt apex, the basal cells, one of which is as large as the rest of the receptacle, forming a short stalk. Spores about $30 \times 5\ \mu$. Perithecium $150 \times 52\ \mu$. Receptacle (including stalk cells of perithecium) $62\ \mu$ long.

On the abdomen of *Bledius basalis* Lec., Florida.

HAPLOMYCES, nov. gen.

Receptacle consisting of two small superposed cells from which arise the single perithecium and the single antheridial appendage. Perithecium large, pointed, borne on a single stalk cell surmounted by two basal cells. Antheridial appendage consisting of a basal cell surmounted by a terminal body, the antheridium, divided by anastomosing septa into numerous small cells and furnished with a short lateral projection, together with a subterminal short spine-like process arising from a rounded base. Asci four-spored, arising from four main ascogenic centres, each of which is divided into two secondary centres.

A very simple type, without sterile appendages, nearly allied to Cantharomyces by the presence of a highly developed cellular antheridium, which in the latter genus is lateral in position and without the characteristic thorn-like tip. The three species described adhere strictly to the generic characters given, and appear to be abundantly distinct.

HAPLOMYCES CALIFORNICUS, nov. sp.

Perithecium faintly olive-brown, inflated at the base; the distal portion curved strongly inwards, the stalk cell hyaline, broad, subtriangular; the basal cells short and broad, the inner larger, its pointed apex extending upwards beyond the ascogenic centre, both more or less suffused with olive-brown. Receptacle small, the basal cell slightly suffused, the distal cell black and opaque, the opacity including the whole of the basal cell of the appendage. Antheridium twice as long as broad, tinged with brown. Thorn-like apiculus prominent, its base well marked. Spores $37–40 \times 3\ \mu$. Perithecia $130–145 \times 65\ \mu$. Stalk cell of perithecium $45–50 \times 38\ \mu$. Anthe-

ridium 33 × 19 μ. Receptacle 45–55 × 15–18 μ. Total length to tip of perithecium 240–260 μ. Total length of antheridial appendage 48–55 μ.

On abdomen of *Bledius ornatus* Lec., California.

Haplomyces texanus, nov. sp.

Perithecia almost symmetrically conical, straw-yellow, the tip rather blunt; the stalk cell nearly hyaline, twice as long as broad, slender at the base; the basal cells elongate, nearly equal; distally almost truncate. Receptacle small, the basal cell nearly hyaline; the distal cell very small, slightly broader than long, blackened and opaque, the opacity including the lower outer portion of the basal cell of the appendage, the unblackened portion of which, together with the antheridium, becomes suffused with brown. Spores 40–45 × 3.7 μ. Perithecia 165–185 × 50–55 μ. Stalk cell of perithecium 65–90 × 26–33 μ. Antheridium 32 × 18 μ. Receptacle 37–45 × 18 μ. Total length to tip of perithecium 315–370 μ. Total length of antheridial appendage 35–40 μ.

On abdomen and elytra of *Bledius rubiginosus* Er., Texas.

Distinguished from the preceding species by its pale yellowish color, conical nearly straight perithecium, and by the elongated basal cells of the latter. What appears to be the young condition of the same species occurred with it, differing in the absence of any blackening of the receptacle or appendage.

Haplomyces virginianus, nov. sp.

Perithecium short, stout, straw-yellow, outwardly inflated, the outer margin curved strongly inwards to the conical distal portion, the apex bluntly pointed; stalk cell long, nearly cylindrical, distally expanded slightly, the basal cells of perithecium very small, almost obsolete. Basal cell of receptacle large, the distal cell very small, and several times as broad as long, the stalk cell of the perithecium arising from it, but also connected with the distal portion of the basal cell. Basal cell of antheridial appendage squarish, slightly broader than long, the antheridium rounded, its reticulations coarse, the thorn-like apiculus very fine (about 5 μ long) and abruptly distinguished from its flattened base. Spores 33 × 3.7–5.5 μ. Perithecia 110–130 × 55–60 μ. Stalk cell of perithecium 75–110 × 19–25 μ. Antheridium 18 μ long, 22–23 μ wide. Receptacle, basal cell 45–50 × 18–19 μ, distal cell about 18.5 × 6 μ. Total length to tip of perithecium 220–275 μ. Total length of appendage 30–33 μ.

On abdomen of *Bledius emarginatus* Say, Virginia.

Distinguished from the remaining species by the great reduction of the basal cells of the perithecium and the distal cell of the receptacle, as well as by the shorter more rounded antheridium.

A further knowledge of the members of the genus previously described under the name of Cantharomyces makes it possible to define its characters more exactly than was at first practicable, and the original diagnosis may be modified as follows.

CANTHAROMYCES, Thaxter, emend.

Receptacle consisting of two superposed cells, the distal producing one or more stalked perithecia, and one or more antheridial appendages. Perithecia subconical, borne on a single stalk cell surmounted by two basal cells. Antheridial appendages consisting of two superposed cells, terminated by one or two cells which may bear several branches, the sub-basal cell divided into two parts longitudinally or obliquely, one of which (the antheridium) is subdivided by anastomosing septa into numerous small cells.

C. Bledii is taken as the type of this genus and the species defined below, together with a third as yet undescribed, correspond strictly to the diagnosis given. *Cantharomyces verticillatus* of a former paper departs distinctly from this type, and should be generically separated; but owing to the scantiness of the available material of this form a description is deferred for the present.

Cantharomyces occidentalis, nov. sp.

More or less suffused with brown. Perithecium rather short, subconical, slightly inflated towards the base; the distal portion very slightly curved outwards, the apex bluntly pointed: stalk cell large cylindrical not exceeding the antheridium; basal cells each several times as long as broad. Basal cell of receptacle very small, the sub-basal cell much larger, inflated without blackening or externally and inferiorly deeply blackened and slightly incurved. Basal cell of the appendage similar to the distal cell of the receptacle, larger and unmodified or similarly blackened: the sub-basal cell large, its upper inner quarter, only, modified by anastomosing septa to form the antheridium, which bulges slightly on the inner side and is more or less pointed inferiorly: the appendage terminated by several superposed cells. Perithecium 96–100 × 60 μ. Stalk cell of perithecium

120–140 × 26 μ. Length of appendage to tip of antheridium 110–150 μ. Total length to tip of perithecium 280–335 μ.

On abdomen of *Bledius armatus* Er., Utah.

Distinguished from *C. Bledii* by its brown color, the greater elongation of the basal cells of the perithecium, and the relatively small antheridium, which in *C. Bledii* is external and comprises about five sixths of the sub-basal cell. The two specimens examined have each a single perithecium, and but one appendage, the tip of which is somewhat broken. A number of young specimens apparently belonging to this species, and occurring on *B. jacobinus* Lec., have the terminal portion of the appendage unbranched and consisting of a short series of superposed cells.

IDIOMYCES, nov. gen.

Receptacle short; flattened, terminated on one side by a series of superposed cells bearing externally a vertical row of closely set appendages, on the opposite side by one or more stalked perithecia at the base of which on one side arises a second transverse series of similar appendages. Perithecia straight, symmetrical, borne on a stalk composed of a single basal and several terminal cells. Appendages consisting of a series of antheridial cells, their projecting necks forming a comb-like appendage which may be terminated by short branches. Spores as in other genera.

The appendages of this curious genus recall those of Stigmatomyces, which is perhaps its nearest ally. The arrangement of these appendages in two series, one upon a differentiated and the other upon an undifferentiated base, is remarkable and peculiar to this genus which is very probably identical with that referred to by Peyritsch * as occurring on Deleaster in Austria.

Idiomyces Peyritschii, nov. sp.

More or less tinged with yellowish or reddish brown. Receptacle consisting of two superposed basal cells, surmounted by two cells; the outer, having a very thick external wall which forms a distinct prominence distally, is succeeded by a row of about five or six superposed, more or less flattened cells, extending beyond the base of the perithecium, which bear externally a vertical series of closely set appendages: the inner is succeeded by a single rounded cell followed by several small cells which give rise to a transverse series of about six appen-

* Sitz. d. Wien. Akad., 1875, LXXII. Abth. 3.

dages. Appendages mostly fertile, borne on one or two squarish basal cells, terminated by a simple or once branched short filament. Perithecia short, thick, subconical, the apex subtruncate, the base slightly inflated, borne on a long stalk made up of a single basal and two subbasal cells, the outer directly in contact with the perithecium, the inner separated from it by two small cells. Spores 60 × 4 μ. Perithecia 110–130 × 60–70 μ. Appendages, longer, 80 μ. Receptacle 130–165 × 70–95 μ. Stalk of perithecium, longest, 200 μ.

On abdomen of *Deleaster dichrous* Grav., Germany.

Laboulbenia umbonata, nov. sp.

Perithecium becoming faintly suffused with brown, projecting free from the receptacle at an angle of about 60°, the outer margin curved inwards strongly to the blackish tip, the prominent ear-like lips of which are strongly incurved; a clearly defined rounded prominence on the inner side below the apex. Outer appendage hyaline, or with faint brown shades, consisting of a large stout cylindrical basal portion nearly equalling the receptacle in diameter and length, made up of a basal and somewhat shorter sub-basal cell from the distal end of which arise two (rarely three) straight, very long and slender tapering branches. Inner appendage arising from a very small triangular basal cell, its external wall directly continued by that of the outer appendage by which its upper surface is covered, its lower half cutting off obliquely a small portion of the large black insertion cell: its upper half producing sublaterally a single short appendage, consisting of a single cell bearing at its apex two rather long antheridia. Receptacle characterized by a stalk-like slightly inflated base, made up of cells (1) and (2), which are very large, the cells of the distal portion except cells (4) and (5) very greatly reduced, so that the perithecium appears to arise almost directly from cell (2). Cells (4) and (5) elongated, the upper half of cell (5) free from the perithecium; the axis of the receptacle coincident with that of the outer appendage. Spores 60 × 5 μ. Perithecia 110 × 59 μ (including the hump which projects about 7 μ). Appendages (longest) 925 μ. Receptacle 155–185 × 18–33 μ.

On right side of thorax of *Stenolophus ochropezus* Say, Maine.

Laboulbenia subterranea, nov. sp.

More or less suffused with brown, or with the two basal cells quite hyaline. Perithecia long, slightly inflated at the base, tapering more or less evenly to the subcylindrical apex, the lips of which are turned

slightly outwards. Appendages arising from two basal cells, the outer very large almost covering the very small inner one and continued directly to form the usually very large long simple outer appendage, which is septate, slightly constricted at the septa with a marked general constriction usually present towards the base, accompanied by a brown suffusion. The inner basal cell gives rise to a single short branch bearing one or two antheridea. The black insertion cell eventually thrust obliquely outwards by cell (5) free from the perithecium. Receptacle sometimes short, more often very long through the elongation of cell (2), the distal portion reduced, usually blackish brown, while the two basal cells are hyaline. Perithecia 135–160 × 50 μ. Outer appendage, longest 1065 μ; average 725 μ. Total length to tip of perithecium 220–480 μ; average 375 μ.

On *Anophthalmus Menetriesii* Motsch., and *A. angustatus* Lec., in limestone caves, Kentucky. On *A. Motschulskyi* Schm., Carniolia.

A peculiar and variable species. Forms occurring on the jaws of the host (a blind cave beetle) are short and compact, while others, especially those occurring on the lower surface of the abdomen, are very elongate. The European specimens are small and rather slender, but can hardly be separated from the American form. A second species of Laboulbenia allied to *L. luxurians* occurs on Anopthalmi from caves in Illinois, but the material is hardly sufficient to warrant its description.

Laboulbenia Catoscopi, nov. sp.

Pale brownish yellow becoming suffused with olive-brown at the base of the perithecium and in the region of cell (3). Perithecium moderate, the apex rather prominent, blackened except about the pore, the blackening continued downwards externally to the body of the perithecium. Outer appendage single simple nearly straight, exceeding the perithecium; its basal cell very large, outwardly inflated and blackened. Inner appendage consisting of a much smaller basal cell, from which arise directly from two to six branches which may be once or twice successively branched; the antheridia solitary. Receptacle rather elongate, normal, cell (4) projecting outwards beyond the rather thick black insertion cell, which is situated between the two lower thirds of the perithecium. Spores 65 × 5 μ. Perithecia 100–130 × 37 μ. Appendages (longest observed) 110–130 μ. Total length to tip of perithecia 250–320 μ.

On the abdomen of *Catoscopus guatemalensis* Bates, Mexico.

Belonging to the *flagellata* group, in which it is at once distin-

guished by the inflated basal cell of the outer appendage. More abundant material may show that the measurements of the appendages given are too small.

LABOULBENIA FILIFERA, nov. sp.

Perithecium tinged with olive-brown, the apex deeply blackened, broad, more or less evenly rounded, often symmetrical. Appendages consisting of two basal cells, the inner minute, the outer large, usually followed by a sub-basal cell from which arise two very elongate simple erect branches, at first dark brown above their nearly hyaline basal cells. The inner appendage consists of one or two short hyaline fertile branches, one of which may be long and sterile. The insertion cell placed between the two lower thirds of the perithecium. Receptacle short, about equalling the perithecium in length, the inner margins abruptly divergent above cell (2). Spores about 50×4 μ. Perithecia, average 25×90 μ. Appendages, longest 550 μ. Total length to tip of perithecium 150–190 μ.

On elytra of *Anisodactylus Harrisii* Lec., *A. nigerimus* Dej., and *A. interpunctatus* Kirby, Maine, Massachusetts, Pennsylvania.

LABOULBENIA COMPRESSA, nov. sp.

Pale yellowish. Perithecia becoming tinged with olive-brown, the lips compressed to form an evenly rounded apex, which is commonly bent slightly outwards and blackish brown except about the pore, which is external and lateral. Appendages consisting of two basal cells, the outer much the largest, bearing a single appendage usually once branched, the lower cells slightly inflated, the ultimate branches straight and tapering. From the inner basal cell arise several branches, some short and fertile, others resembling the longer outer appendage. Insertion cell placed just below the middle of the perithecium. Receptacle normal, the basal cell usually curved. Spores 50×3.7–4 μ. Perithecia 85–100 $\times$ 30 μ. Appendages, longest 150–200 μ. Total length to tip of perithecium 175–260 μ, average 210 μ.

On elytra and at base of middle pair of legs of *Anisodactylus baltimorensis* Say, Maine.

Easily separable from other forms by its peculiarly pointed perithecium.

LABOULBENIA POLYPHAGA, nov. sp.

Perithecium slender, the outer edge nearly straight, with a more or less well marked prominence below the apex; the tip prominent,

rather narrow, bent outwards, deep black, hyaline about the pore, with brown shades more or less well marked below the tip and about the lower half. Appendages two, the outer consisting of a large basal cell, which may be continued directly to form a long simple straight appendage distinctly constricted at the joints, or may bear two similar branches. The inner basal cell bears one or two short branches, from which arise small clusters of brownish antheridia, and rarely a more elongate sterile branch. Receptacle rather slender, a more or less well marked brown suffusion usually present in the distal portion. Spores 45 × 4 μ. Perithecia, average 85 × 30 μ. Appendages, longest 300 μ. Total length to tip of perithecium, average 200–220 μ.

On elytra of *Olisthopus parmatus* Say, Maine; *Stenolophus limbalis* Lec., Washington; *Badister maculatus* Lec., Texas; *Harpalus pleuriticus* Kirby, Massachusetts. A carabid near Stenolophus, Brazil.

This form, although presenting no striking peculiarities of structure, seems sufficiently well defined to warrant its separation as a distinct species. It is nearly allied to *L. Pterostichi*, but differs in its small size and more simple appendages. A form apparently identical with it occurs on several species of *Loxandrus* from Florida and Texas. The specimens on Badister are more or less evenly suffused with brownish yellow, due perhaps to age and alcohol.

Laboulbenia Pterostichi, nov. sp.

Becoming more or less, often deeply, suffused with olive-brown. Perithecium becoming deeply suffused, the outer margin commonly straight, the apex rather coarse-lipped. Outer appendage consisting of a large basal cell, above which it is usually three times successively dichotomously branched, the ultimate branches long, straight, the outer ones especially tinged with reddish brown. Inner appendage consisting of a small basal cell giving rise to from one to three short branches bearing one to several fertile branchlets, sometimes also to one or more long sterile branches. Receptacle normal, usually elongate. Spores 75–80 × 6.5 μ. Perithecium 130–160 × 48–55 μ. Appendages (longest) 725 μ, average 400–500 μ.

On *Pterostichus adoxus* Say, and *P. luctuosus* Dej., Maine; *P. mancus*, Southern States.

A form closely allied to *L. elongata*, from which some of its varieties can hardly be distinguished. The usual absence of sterile branches in the inner appendage and the character and branching of the outer

appendage serve to distinguish it. It is nearly allied also to the smaller *L. polyphaga*.

Laboulbenia europæa, nov. sp.

Amber-brown. Perithecium darker amber-colored, rather narrow, its tip nearly straight, broad, black except the edges of the coarse lips, which are turned slightly outwards, an olive shade extending below the blackened portion. Outer appendage hyaline, suffused below with olive-brown deeply colored externally near the base, simple or more commonly consisting of a basal and a sub-basal cell which bears two long slender tapering branches: more rarely the basal cell bears two branches directly, the inner simple, the outer bearing two branches from its basal cell. Inner appendage consisting of a basal cell which may bear two branches directly, or more commonly is followed by a sub-basal cell bearing a long simple sterile branch and a shorter fertile branch producing several antheridia and one or two sterile divisions which sometimes become elongate. Receptacle normal, a very slight olive suffusion of the external surface of cell 4. Spores 55–59 × 4–4.5 μ. Perithecia 130–140 × 55 μ. Appendages (longest) 250 μ. Total length to tip of perithecium 250–300 μ.

On *Chlænius æneocephalus* Dej., *C. chrysocephalus* Rossi, *Callistus lunatus* Fabr., *Aptinus mutilatus* Fabr., Europe.

Allied to *L. Pterostichi*, from which it is readily separated by its amber color, its sparingly branched appendages, and by the shape of its perithecium.

Laboulbenia Quedii, nov. sp.

Perithecium moderate, straight, slightly suffused with brownish, darker externally just below the apex, the lips turned outwards, the outer hyaline, the inner blackened. Outer appendage consisting of a rather large basal cell bearing two branches, the outer strongly curved outwards, usually bearing two secondary branches from its basal cell suffused with blackish; the inner also similarly branched, the branches long, tapering to a blunt point, often suffused with brown near the base. The inner appendages commonly arise from two basal cells, the inmost smaller and lower in position, each giving rise to a variable number of appendages, usually not more than once branched, hyaline except the outer one which is larger and usually suffused with brown near its base. Receptacle elongate. Spores about 55 μ long. Perithecium 185 × 50 μ. Longest appendages 370 μ. Total length to tip of perithecium 630 μ.

On the upper surface of abdomen of *Quedius vernilis* Lec., Illinois.

The insertion cell of the appendages in this species is broad and remains hyaline until the plant is nearly mature, when it is not very deeply blackened.

Laboulbenia proliferans, nov. sp.

Reddish brown more or less tinged with olive. Perithecia tinged with olive, darker below the hyaline lips, normal in form. Appendages consisting of two closely united basal cells nearly equal, seated on a thick black insertion cell, and bearing usually two simple branches, the outer longer. The appendages with their insertion cell are pushed outwards from the perithecium by the enlargement and division of cell (5), from the upper part of which one or two small cells may be cut off by oblique partitions, each becoming proliferous and producing a simple appendage similar to and equalling the normal appendages. Receptacle elongate, normal except for the proliferation of cell (5). Spores 60–70 × 5.5 μ. Perithecia 165–170 × 55 μ. Longest appendages 460 μ. Total length to tip of perithecium 435–540 μ.

On elytra of *Eudema tropicum* Hope, Sierra Leone; "*Chlænius auricollis* Gory, Syria"; Dolichus sp. ?, Japan.

A large species at once distinguished by the proliferation of cell (5). The material from Syria and Japan, though in poor condition, is identical with that from Africa.

Laboulbenia Coptoderæ, nov. sp.

More or less suffused with faintly olive brown. Perithecium rather large, the apex, which is bent slightly outwards, dark, the lateral lips forming a slight angular prominence over the lateral external pore. Appendages two, the outer single, curved outwards, blackened externally or wholly opaque, giving rise from its convex side to several successive branches rather irregular in outline and often once branched above their basal cells. Inner appendage consisting of a larger basal cell which gives rise from its apex on either side to a branch, these two branches in turn successively several times branched, but in a plane at right angles to their own; the lower cells more or less deeply suffused or externally blackened. Receptacle normal, cell (2) of large diameter. Spores 40 × 3.5 μ. Perithecia 100–110 × 33–35 μ. Appendages (longest) 150 μ. Total length to tip of perithecium (average) 200 μ.

On *Coptodera Championi* Bates, Panama, growing along the outer margin of the elytra.

LABOULBENIA MORIONIS, nov. sp.

Pale straw-colored throughout except for a slight blackish brown shade below the apex of the perithecium. Perithecium small, narrow, its whole inner margin connected with the receptacle, beyond which the rather truncate hyaline tip barely projects. Appendages inconspicuous, consisting of two basal cells each of which may bear one to three short branches. Receptacle elongate, somewhat wedge-shaped, the small blackened insertion cell carried outwards with the appendages free from the perithecium. Spores $55 \times 5\ \mu$. Appendages $40–50\ \mu$. Perithecia $110–125 \times 30\ \mu$. Total length to tip of perithecium $375–425\ \mu$. Greatest width including perithecium $50\ \mu$.

On the elytra of *Morio georgiæ* Pal., Mexico.

A singular species allied to the last, its small perithecium scarcely distinguishable, at first sight, from the body of the receptacle. The appendages are almost obsolete in some specimens.

LABOULBENIA CLIVINÆ, nov. sp.

Hyaline or tinged with straw-yellow. Perithecium rather broad, its tip only free from the receptacle, short, the inner margin curved abruptly outwards from the receptacle to the blunt apex, the lips of which are turned outwards, the upper hyaline with a slight brown suffusion. Appendage usually *single* arising from cell (4) or from cells (4) and (5) directly without any blackened insertion cell: consisting of a basal cell simple or longitudinally divided, above which it may be successively several times branched. A second appendage is rarely present, arising apparently from the upper division of cell (5). Receptacle hyaline, elongate, normal, except for cells (4) and (5), which become more or less irregularly divided into from four to eight smaller cells. Spores $75 \times 5\ \mu$. Perithecia $145–150 \times 55–60\ \mu$. Appendage $110–150\ \mu$. Total length to tip of perithecium (maximum) $400\ \mu$.

On the elytra, thorax, and legs of *Clivina dentifemorata* Putz., Mexico.

This species is remarkable for possessing usually but a single appendage, and from the absence of any blackened insertion cell, which may, however, be represented by the upper apparent divisions of cells (4) and (5). The species is allied to, though abundantly distinct from, *L. Schizogenii*, which occurs on a closely related host.

LABOULBENIA PHEROPSOPHI, nov. sp.

Perithecium becoming suffused with blackish-brown, straight, the two upper thirds free from the receptacle, rather slender, the outer margin curving abruptly inwards to the base of the prominent tip, which is itself bent slightly outwards, its base deeply suffused. Outer appendage slightly divergent, somewhat exceeding the perithecium, composed of usually five or six superposed cells somewhat longer than broad, each of which gives rise externally from its upper half to a single simple short branch, tapering distally, slightly constricted near the base where it is divided by a blackened septum: insertion cell rather broad, black, and considerably exceeded externally by the free upper surface of cell (4). Inner appendage smaller and similar or once to twice subdichotomously branched above its basal cell, the lower septa blackened. Receptacle normal cell (2) usually hyaline, the rest becoming suffused with olive-brown. Spores 75 × 4.5 μ. Perithecia 150 × 50 μ. External appendage 100–150 μ, its branches about 50 μ long. Total length to tip of perithecium 250–500 μ.

On *Pheropsophus æquinoctialis* Linn. and several undetermined species from South America. On *P. marginatus* Dej. var.? from Zanzibar.

LABOULBENIA PANAGÆI, nov. sp.

Perithecia becoming wholly suffused with blackish brown, straight, thick-walled, cylindrical or slightly inflated, the apex truncate or slightly oblique outwards, the outer lip nearly hyaline. Appendages arising opposite the base of the perithecium, consisting of two equally broad basal cells, the inner shorter, bearing each a single cell from which arise from three to five usually simple branches hardly exceeding the perithecium, the lower cells usually inflated, the septa blackened, as is the outer wall of the external basal cell. Receptacle normal, cells (3) and (4) blackened externally or wholly, the suffusion becoming general in older individuals in which the basal cells of the perithecium may become elongated to form a neck-like base free from the insertion cell of the appendages which becomes pushed out quite free from the perithecium by the elongation of cells (4) and (5). Perithecia 100–150 × 35–40 μ. Longer appendages 250–330 μ. Total length to tip of perithecium 240–330 μ.

On elytra and thorax of *Panagæus crucigerus* Say, and *P. fasciatus* Say, Southern United States.

Specimens occurring upon *P. crucigerus* are decidedly larger than

those observed upon the smaller species. The form belongs to the group of which *L. Galeritæ* may be taken as the type, in which the base of the cylindrical thick-walled perithecium tends to become elongated to form a neck-like insertion. The host affected is one of the myrmecophilous Carabidæ inhabiting ants' nests.

LABOULBENIA AUSTRALIENSIS, nov. sp.

Perithecia as in the preceding species, less deeply suffused and supported in older individuals by a more or less neck-like base. Appendages consisting of two closely united basal cells; the outer much the largest, and giving rise directly to two branches, the outer deeply suffused with olive-brown, the inner once or twice branched, hyaline or with suffused tips. The inner basal cell gives rise to one or two branches, simple or once or twice branched: the insertion cell black, thick and rather narrow, placed opposite the base of the perithecium. Receptacle normal, except for the eventually neck-like hyaline base of the perithecium, hyaline becoming suffused with olive-brown, especially in the region of cells (2), (3), and (6). Spores 74 × 5.5 μ. Perithecia 110–148 × 38 μ. Longest appendages 222 μ. Total length to tip of perithecium 220–300 μ.

On elytra of *Acrogenys hirsuta* McLeay, Australia.

Closely allied to *L. Panagæi*, from which it is distinguished by its appendages, which are longer, the outer branch blackened and the basal joints not inflated.

LABOULBENIA MEXICANA, nov. sp.

Pale amber-colored, the basal cell and mature perithecium more deeply suffused. Perithecia large, straight, thick-walled, the black hyaline-lipped apex abruptly distinguished, nearly symmetrical. Appendages hardly exceeding the perithecium, consisting of two basal cells, the outer giving rise to two branches, an outer usually simple, more deeply suffused, and an inner larger, once or twice branched. From the inner basal cell arise two branches on either side, once or twice successively branched, and bearing a few single antheridia laterally. Receptacle elongate, often abnormally septate, the basal cells of the perithecium extending upwards about the ascogenous area and forming a broad more than usually elongate base. Spores 90–100 × 7 μ. Perithecia 200–240 × 65 μ. Appendages, longest, 220 μ. Total length to tip of perithecium 500–600 μ.

On elytra of *Galerita mexicana* Chaud., *G. nigra* Chev., *G. æquinoctialis* Chaud., Mexico and Nicaragua.

A few specimens suggesting a hybrid between this species and the nearly allied *L. Galeritæ*, which occurs in company with it, were found on a specimen of *G. mexicana* from Nicaragua associated with the normal form. In the variety the appendages and receptacle are those of *L. mexicana*, while the perithecium with its slender neck-like base, although not punctate, is that of *L. Galeritæ*.

Laboulbenia longicollis, nov. sp.

Perithecia becoming suffused with dark brown, straight, thick-walled, often slightly inflated, the apex short, rather large, abruptly distinguished, black, its lips hyaline turned slightly inwards. Appendages consisting of two basal cells, the inner smaller, bearing distally two rounded cells, the upper surface of each blackened and bearing two to five branches which arise side by side and spreading laterally may be successively and similarly twice branched, the whole having a fan-like habit, the ultimate branches usually one to three in number, either bearing two to three long-necked antheridia, or sterile, somewhat elongate, straight and tapering. The outer basal cell superiorly and externally blackened, the blackened ridge extending obliquely outwards and downwards nearly to the base, bearing a row of closely set branches of variable number (three to five) which are successively three to five times dichotomously branched, the ultimate branches suffused with brown, straight, slender, tapering; the basal cells of all the main branches hyaline, slightly inflated inwardly, the septa black, contrasting. Receptacle large, cell (5) as large or nearly as large as cell (4), the basal cells of the perithecium about 175 μ in length. Spores $75 \times 6.5\ \mu$. Perithecium $180–220 \times 50–60\ \mu$. Longest appendages 510 μ. Total length to tip of perithecium 500–780 μ.

On elytra of *Galerita leptodera* Chaud., Guinea.

A very large species, allied to *L. Galeritæ* and *L. mexicana*, from which it is distinguished by its complicated and highly developed appendages, and the remarkable elongation of the base of the perithecium.

Laboulbenia texana, nov. sp.

Perithecium wholly suffused with blackish brown, short, its upper half free, the outer edge abruptly curved inwards to the base of the very prominent apex, the lips of which are brown, slightly pointed. Appendages two, hyaline, almost distinct above the very broad black insertion cell, the outer broad at the base, tapering distally, strongly curved inwards, rather closely septate, a small cell opposite each sep-

tum on the convex side, bearing a single short simple branch rather closely septate, hyaline, blackened and constricted at the base, directed obliquely upwards. The inner appendage similar, except that a cell is present opposite the first septum at the base on the *inner* side, which bears a single autheridium or a very short fertile branch. Receptacle expanded above cell (2), cells (1) to (6) hyaline, the rest blackish brown: cell (5) greatly enlarged so as to throw the appendages outwards, separating them by nearly its whole width from the perithecium, its free upper surface forming a right angle with the straight inner margin of the perithecium; cells (1) and (2) rather slender. Perithecia 130–150 × 65 μ. Appendages 150–160 μ, the branches (longer) 75–100 μ. Length to tip of perithecium 400 μ. Greatest width 110 μ.

On the thorax of *Brachinus* sp., Texas.

One of the most peculiar of all the species of Laboulbenia, the appendages of which are approached only by *L. Pheropsophi*.

LABOULBENIA PACHYTELIS, nov. sp.

Perithecium rather small, but slightly exceeding the receptacle, suffused with dark olive-brown, becoming nearly opaque, tapering abruptly to the rather slender blackened tip, which is bent slightly outwards, the nearly hyaline lips outwardly oblique. Appendages two; the outer forming a subconical body composed of superposed flattened cells four to ten in number, each cell giving rise externally to a single obliquely ascending, rather short, simple, stout, tapering branch, blackened at its base, where a basal cell is cut off by a contrasting black septum. The inner appendage consisting of a small basal and sub-basal cell separated by a blackened septum, the upper giving rise directly to from one to three antheridia or short sterile branches. Receptacle short or elongate, nearly hyaline or becoming distally suffused with blackish brown, normal, except for the unusual development of cell (5), which extends along the inner margin of the perithecium beyond the insertion of the appendages, pushing them outward free from the perithecium. Spores 66 × 7 μ. Perithecia 110–150 × 50 μ. Outer appendage, without branches, 90 μ long, the branches (longest) 180 μ. Total length to tip of perithecium 300–650 μ.

On legs and inferior surface of *Pachyteles mexicanus* Chaud., Mexico.

Laboulbenia cristata, nov. sp.

More or less suffused with brown. Perithecium curved outwards, evenly often deeply suffused with brown, tapering to the neck-like apex, its prominent lips turned outwards, the base of the inner lip more deeply suffused. Appendages two, the outer consisting of a large squarish cell surmounted by a sub-basal cell which bears on its upper flattened surface a series of from three to six large straight simple septate dark brown branches set side by side in a single row running from within outwards, the inner very long, the outermost basally deeply blackened and contracted, curved strongly outwards, its hyaline distal portion commonly broken off. The inner basal cell very small, producing usually two short branches bearing groups of large long-necked antheridia. Trichogyne large, branched and septate, the ultimate branches straight and tapering. Receptacle short, stout, hyaline becoming tinged with yellowish brown. Cell (1) small, cell (2) very large, all very thick-walled. Spores 50–55 $\times$ 4–4.5 μ. Perithecia 110–130 $\times$ 37–45 μ. Appendages (outer not including two basal cells) 90–480 μ, basal cells 35 μ. Total length to tip of perithecium 250–280 μ.

On elytra, abdomen, and legs of *Pæderus littorarius* Grav. and *P. obliteratus* Lec., Maine; *Pæderus* sp.? Mexico and Nicaragua; *Pæderus ruficollis* Fabr., Austria.

A species not to be confused with any other, owing to the crest-like outer appendage, which, however, varies considerably in the number of its branches. This is perhaps the form referred to by Rouget as occurring on *Pæderus* in France, and confused by him with *L. Rougetii* Robin.

Laboulbenia Philonthi, nov. sp.

Perithecium rather narrow, subconical, slightly inflated at the base, blackened along the margin below the hyaline lips which are turned slightly outwards. Appendages consisting of two basal cells, including, between and below them, a small triangular cell: the outer appendage simple or rarely once branched, its sub-basal cell commonly inflated with blackened septa. The inner basal cell gives rise to numerous branches which are straight, simple, or once to twice branched, the branchlets straight divaricate, hyaline, tapering to a blunt tip hardly exceeding the perithecium, their basal cells often more or less inflated, brownish with blackened septa. Insertion cell opposite the base of the perithecium. Receptacle usually short. Spores 52

× 4 μ. Perithecia 160–165 × 50–70 μ. Longest appendages 165 μ. Total length to tip of perithecium 400–450 μ, longest 590 μ.

On *Philonthus cunctans* Horn, Maine; *P. micans* Grav. and *P. debilis* Grav., Massachusetts; *P. æqualis* Horn, Lake Superior; *P. californicus* Mann, California.

The specimens on *P. micans* from Sharon, Mass., found growing on the upper surface of the abdomen of the host, though exactly resembling the typical form in other respects, have the basal cell of the receptacle obliquely produced to form a rounded prominence which is externally deeply blackened and forms a hoof-like base. The species is not strikingly peculiar, its appendages recalling those of *L. inflata*. It approaches the *luxurians* type through the presence of a third cell between the basal cells of its appendages, and is not to be confused with either of the other species known to occur on Staphylinidæ.

Laboulbenia zanzibarina, nov. sp.

Olive-brown except for the nearly hyaline basal cell. Perithecia large, more deeply colored below the somewhat suffused lips, the apex prominent, straight, truncate, hardly oblique. Appendages consisting of two, sometimes three, basal cells (the inner sometimes the larger), longer than broad, bent with their convexity outwards, externally blackened, giving rise to from one to several branches from the outer surface of their upper portions; the basal cell of each branch is also curved with its convexity outwards, externally blackened, and gives rise in a similar fashion to several secondary branches, the basal cells of which show the same tendency to curvature and bear a series of several ultimate branchlets from their distal portions, exceeding the perithecium often by more than its length. Receptacle becoming nearly opaque, except for the very small hyaline basal cell, stout and short, cells (2) and (6) placed almost side by side. Spores about 50 μ long. Perithecia 100–110 × 3.7 μ. Appendages (longest) 200 μ. Total length to tip of perithecium 185–200 μ.

On *Crepidogaster bimaculata* Boh., Zanzibar, occurring at the tips of the elytra and the adjacent upper surface of the abdomen.

Laboulbenia minima, nov. sp.

Punctate, suffused with olive-brown, becoming nearly opaque, except the hyaline basal cell. Perithecia becoming rounded in outline, short, the apex broad truncate, coarse-lipped, distinctly punctate and nearly opaque at maturity. Appendages arising from a rounded base of insertion, composed of several cells and not distinguished from

the receptacle, densely clustered, the lower segments nearly hyaline, oval or rounded, with black septa, the ultimate branches cylindrical, hyaline, strongly curved towards and beyond the perithecium. Receptacle very short and stout, the basal cell curved and hyaline. Spores 40 × 3.5 μ. Perithecia 80 × 40–48 μ. Appendages (longest) 75 μ. Total length to tip of perithecia 145–150 μ.

On elytra and legs of *Calleida pallidipennis* Chaud., Panama.

The smallest known species of the genus belonging to the *luxurians* type.

LABOULBENIA GUERINII, Robin.

A form occurring on *Gyretes compressus* Lec. and *G. sinuatus* Lec., from Illinois and Texas, seems identical with the species figured by Robin, though somewhat smaller.

LABOULBENIA ANCEPS, Peyr.

A form common on *Platynus extensicollis* and several other species of the genus seems referable to this species, and is not separable from specimens found on *Anchomenus* (*Platynus*) *albipes*, from Austria. It is subject to considerable variation, and is perhaps too near *L. elongata* and *L. Rougetii*.

ACANTHOMYCES, Thaxter.

Several additional species of this genus correspond strictly to the type previously described, except that additional material shows the occasional production of two perithecia usually accompanied by a corresponding elongation of the receptacle.

ACANTHOMYCES LONGISSIMUS, nov. sp.

Perithecium brown, darker at the blunt apex, slightly inflated, its two lower thirds almost completely surrounded by a series of appendages arising from its base. Receptacle very long and slender, slightly flexuous, its main axis consisting of about thirty superposed cells deeply suffused with blackish brown, lighter at the septa. Appendages very numerous, externally opaque, internally more or less hyaline, short, slender, straight, appressed; a few curved, projecting outwards on either side in successive pairs. Spores 60 × 4 μ. Perithecium 185 × 55 μ. Appendages about 110 μ long, those at the base of the perithecium about 165 μ. Receptacle slightly exceeding a millimeter in length by 30 μ broad.

On elytra of *Colpodes evanescens* Bates, Guatemala.

ACANTHOMYCES HYPOGÆUS, nov. sp.

Perithecium nearly sessile, terminal, pale straw-colored, hardly inflated, continuing the sigmoid curve of the receptacle, its blunt apex exceeding the tips of the appendages by about half its length. Receptacle uniformly pale straw-colored, bent in a sigmoid curve, the base slender, the remaining portion stout, the main axis consisting of about eighteen superposed cells with very oblique septa. Appendages numerous, closely set, appressed, slightly curved inwards, deep brown, the tips paler. Perithecium 145 × 37 μ. Appendages 110–150 μ. Receptacle 340 × 37 μ.

On the elytra of *Anophthalmus Bilimeki* Sturm., Carniolia, Austria.

ACANTHOMYCES FURCATUS, nov. sp.

Perithecium more or less suffused with brownish, straight, slightly inflated at the base, tapering gradually to the apex, borne on a stout stalk cell surmounted by several small basal cells. Receptacle more or less tinged with brownish, its main axis consisting of about twelve superposed cells, continued by a more slender prolongation beyond the base of the perithecium, this prolongation sometimes forming a second successive main axis terminated by a second perithecium and continued by a similar prolongation beyond the base of this second perithecium which arises on the side of the general axis nearly opposite to that which bears the first. Appendages dark brown, opaque, stout, rigid, nearly straight or slightly curved outwards, the longest not equalling the tip of the perithecium. Spores 48 × 4 μ. Perithecia 160–185 × 48–55 μ. Appendages (longest) about 150 μ. Total length to tip of receptacle about 360 μ. Main body of receptacle about 220 μ long. Total length when two perithecia present (longest) 550–600 μ.

On abdomen of *Othius fulvipennis* Fab., Germany.

ACANTHOMYCES BREVIPES, nov. sp.

Perithecium suffused with reddish brown, subfusiform with a well developed stout stalk. Receptacle very short, the main axis consisting usually of five superposed cells, with a short prolongation beyond the base of the perithecium, normally of not more than three or four cells, the cells all pale yellowish or with brown suffusions, the septa in all cases usually hyaline. Appendages few in number, opaque or nearly so, scattered, some of them very long, curved, and greatly ex-

ceeding the tip of the receptacle. Spores 55 × 4 μ. Perithecium 150–165 × 45–55 μ. Receptacle, main body about 75 × 30 μ, its prolongation about 35–40 μ. Stalk of perithecium about 40 × 30 μ. Appendages (longest) 375–500 μ.

On abdomen of *Lathrobium fulvipenne* Grav., Germany.

A small species, distinguished by its short receptacle and elongate appendages. As in *A. furcatus*, the receptacle may continue to grow, producing in a similar fashion one or even two additional perithecia. This phenomenon, however, seems in both cases to be usually associated with non-fertilization of the trichogynes, or with accidental injury to the perithecia first formed.

Acanthomyces Lathrobii, nov. sp.

Perithecium becoming slightly suffused with brown, its conical tip dark brown, contrasting; rather slender, slightly inflated towards the base, borne on a short stalk cell more or less concealed. Receptacle consisting usually of eight to ten superposed cells, forming the main axis and deeply suffused with blackish brown except at the nearly hyaline septa. Appendages large, curved, almost opaque, nearly equalling, often greatly exceeding the tip of the perithecium. Spores about 50 × 4 μ. Perithecia 100–130 × 35–40 μ. Appendages (longer) 150–450 μ. Receptacle (average) 110 μ long.

On abdomen of *Lathrobium longiusculum* Grav., New Hampshire and Lake Superior; *Lathrobium* sp., Pennsylvania.

The appendages of the specimens from New Hampshire are constantly far longer than those of the Lake Superior specimens, resembling *A. brevipes* in this respect. The two forms seem otherwise identical, and are distinguished from *A. brevipes* by the characteristically brown-tipped perithecium, longer receptacle, and more densely crowded appendages.

CHÆTOMYCES, nov. gen.

Receptacle slender, consisting of numerous superposed cells, from which arise successively the appendages and one or more perithecia in a unilateral series. Perithecium flattened, the symmetrical apex prominent, borne on two stalk cells surmounted by several basal cells. Fertile appendages arising from cells of the receptacle immediately below the perithecium; sterile appendages arising from its terminal cells. Spores as in other genera.

CHÆTOMYCES PINOPHILI, nov. sp.

Perithecium suffused with purplish, more deeply at the base and along its inner half, long, slender; the inner margin nearly straight, the outer curving inward distally to the prominent somewhat angularly inflated tip; the stalk cells bent upward at the base, so that the axis of the perithecium is nearly parallel to that of the receptacle, the lower short and narrow, the upper becoming distally as broad as the perithecium, the basal cells of which are not distinguished from it and are similarly suffused with purplish. Receptacle bristle-like, composed of about fourteen superposed subcylindrical or somewhat flattened cells, almost or quite opaque and indistinguishable, the series usually bent backwards at the base and, more abruptly, at the apex. Of these cells the three (rarely four) basal ones bear no appendages; above these one to three cells may bear fertile appendages, and are in turn succeeded by one, rarely two cells, from which are produced single perithecia; above these follow two to four cells without appendages, while the series is completed by five or six distal cells bearing short stout sparingly branched tapering hyaline sterile appendages. Fertile appendages hyaline, sparingly branched, the antheridia irregularly placed. Spores very slender and sharply pointed $37 \times 1–1.5\ \mu$. Perithecia (including basal cells) $90–130 \times 22\ \mu$; stalk cells about $30\ \mu$ long by $18.5–22\ \mu$ distally, $11\ \mu$ wide at base. Total length of receptacle $150–165 \times 7.5–8\ \mu$. Appendages (longer) about $50–60\ \mu$.

On abdomen of *Pinophilus latipes* Er., Southern States.

RHADINOMYCES, nov. gen.

Receptacle consisting of two superposed cells, from the upper of which arise one to several stalked perithecia and an antheridial appendage. The appendage consisting of a series of several superposed cells, each of which may bear from its distal end one or more short fertile branches producing flask-shaped antheridia more or less irregularly: the distal cell of the series terminated by one or more long sterile branches. Perithecia subconical, borne on a stalk made up of a single basal cell surmounted by several smaller cells. Spores as in other genera.

Two well marked species corresponding exactly in essential characters seem to distinguish this genus from the allied Corethromyces. In both the appendage consists of three superposed cells, though this number may prove variable. The fertile branches consist of two or three small cells bearing the antheridia more or less irregularly, and

arise from small cells cut off from the upper corners of the cells of the appendage, more commonly on the inner side, sometimes on both. Rarely a similar fertile branch may arise at the base of the appendage.

Rhadinomyces pallidus, nov. sp.

Hyaline becoming yellowish or faintly brownish. Perithecium elongate, distally subconical, bluntly pointed. Appendage consisting of three superposed cells, the distal bearing one to three or four stout tapering flexuous branches. Spores 50–55 × 3.5–4 μ. Perithecia 110–185 × 35–40 μ. Receptacle 37–55 × 20–30 μ. Primary appendage 50–200 μ, its branches (longest) 350–375 μ. Stalk of perithecium (larger) 90–110 × 25–30 μ.

On *Lathrobium punctulatum* Lec. and *L. angulare* Lec., Massachusetts. On *L. fulvipenne* Grav., Germany.

The European specimens of this species, though distinctly larger than the American, correspond in all essential characteristics. The receptacle may rarely produce three perithecia, two being not uncommonly present.

Rhadinomyces cristatus, nov. sp.

Perithecia nearly hyaline or slightly yellowish, blunt, tapering slightly, its stalk elongate. Appendage stout and long, its distal cell bearing a crest-like series of three to six or more dark reddish brown rigid, straight, erect, simple, cylindrical branches. One or more similar branches may also arise from the distal end of the middle cell of the receptacle. Spores 50 × 4 μ. Perithecium 110 × 32 μ; its stalk (longest) 280 × 19 μ. Receptacle (largest) 165 × 28 μ. Main appendage (largest) 185 × 19 μ; its branches (longest) 350 μ.

On *Lathrobium nitidulum* Lec., Kittery, Maine, and Cambridge, Mass.

CORETHROMYCES, Thaxter.

In addition to further material of the type species of this genus, several allied forms have been obtained, two of which are described below. Although these correspond in structure to the type, they furnish data which indicate that the limitation of the receptacle to the basal cells (apparently always two) from which the perithecium and the compound appendage were considered to arise directly, cannot be correct, from the fact that a second perithecium is not infrequently developed above the first from the basal cell of the supposed appendage. The main, usually black and opaque, portion of this structure

must therefore be considered the distal portion of the receptacle from which the appendages proper arise. The antheridia appear to be represented by certain short hyaline branches of the inner appendage, but their exact nature cannot well be made out from the dried material. The trichogyne is at first terminal and is well developed.

Corethromyces Cryptobii, Thaxter.

Specimens occurring on *Cryptobium bicolor* Grav., from Pennsylvania, show that the mature perithecium is very elongate, exceeding the tips of the appendages by about half its length, subcylindrical, slightly inflated at the base, the apex abruptly conical, blunt symmetrical: borne on a stalk consisting of a single basal, two sub-basal, and a few small distal cells, on which the perithecium is seated. Perithecium $240 \times 38\ \mu$, its stalk $145 \times 26\ \mu$; basal cell hyaline brown at base, the remaining cells together with the perithecium reddish brown.

Corethromyces setigerus, nov. sp.

Perithecium yellowish, slender, slightly tapering, bluntly pointed: basal cell of stalk hyaline to its base, long; sub-basal cells squarish. Appendages arising from the distal and sub-distal cells of the receptacle, consisting of two or three rounded basal cells, which bear numerous long straight cylindrical septate deep brown branches, the whole curved slightly outwards and forming a crest-like structure. Receptacle consisting of five superposed cells, the four distal ones more or less rounded or squarish, deeply blackened externally, bent outwards at an angle of 45–60°, the perithecium with its stalk cells continuing directly the axis of the basal and sub-basal receptacle cells. Perithecia $110 \times 35\ \mu$. Spores (measured in perithecium) $30 \times 4\ \mu$. Total length of appendages $200\ \mu$ or more. Two basal cells of receptacle $35 \times 15\ \mu$. Total length from base to tip of perithecium 200–220 μ.

On thorax of *Lathrobium nitidulum* Lec., Massachusetts.

This is a much smaller species than *C. Cryptobii*, at once distinguished by its short primary and very long secondary appendages, the series of which recalls that of *Laboulbenia cristata*.

Corethromyces jacobinus, nov. sp.

Perithecia (not fully mature) faintly brownish, nearly hyaline, tapering to a blunt apex. Appendages consisting of two more or less suffused basal cells, from which arise several stout branches them-

selves once or twice branched, the branches as a whole diverging slightly, the inner members of the group hyaline, the outer more or less deeply suffused with brown. A few additional short simple branches may also arise from the tip of the distal cell of the receptacle. Receptacle completely suffused and almost opaque, except the basal cell, which is hyaline with a basal brown suffusion. Perithecia 75 × 22 μ (not quite mature). Total length of appendages 160 μ or more. Two basal cells of receptacle 38 μ. Total length to tip of perithecium 150 μ or more.

On upper surface of abdomen of *Lathrobium jacobinum* Lec., California.

This species is closely related to the preceding, from which it differs by its proportionately larger opaque receptacle, as well as by the character of its appendages, the main axes being more highly developed though less clearly marked than in *G. Cryptobii.*

TERATOMYCES, nov. gen.

Receptacle consisting of several superposed cells surmounted by a series of smaller cells which surround certain central cells, from which the perithecia arise, and produce distally a circle of appendages from within which the long stalked perithecium is exserted. Perithecia one or more in number, symmetrical, the stalk consisting of an elongate basal and three distal cells. Appendages consisting of one or more superposed cells, each producing externally a single row of branches. Spores as in other genera.

The dense tuft of appendages in this singular genus completely obscures the base of the stalk of the perithecium so that the structure in this region cannot be made out. The appendages are quite different in character from those of other described genera, the flattened basal or sub-basal cells being closely set externally with peculiar branches corresponding in position to zigzag depressions of the outer surface of such cells. What the limitations of the generic characters may prove to be it is difficult to determine. The antheridia may be represented by short hyaline branches, at the tips of the appendages.

Teratomyces mirificus, nov. sp.

Receptacle consisting of three (?) superposed cells, the basal one slender, its upper portion opaque and indistinguishable from the cell above it, which is also almost wholly opaque with a partly hyaline

rounded prominence on one side; the third cell of the series is symmetrically expanded upwards, large and broad, more or less tinged with brown and surmounted by the circle of appendage bearing cells (about fifteen in number), which are more or less irregular in size and subtriangular in outline. The appendages consist commonly of a single large long slender flattened cell, its external surface bearing very numerous branches succeeding one another in a single vertical row, the lowest ones simple, beak-like, curved outwards; others higher up bearing beak-like branchlets, while certain of the upper branches may resemble the main cell from which they arise, and like them bear one or more terminal branchlets which may in turn be more or less copiously branched, the whole forming a dense tuft about the stalk of the perithecium of very complicated structure. Perithecia, one or two in number, arising from cells indistinguishable within the circle of appendages, straight, basally slightly inflated, distally subcylindrical and tapering abruptly to a symmetrical truncate apex; borne on a very elongate stalk which raises them far above the appendages and consists of a cylindrical very long basal cell terminated by three cells, one as long as and opposite the other two. Spores $40 \times 4\ \mu$. Perithecia $120–140 \times 22–26\ \mu$. Stalk (longest) $480\ \mu$. Appendages (longest) $185\ \mu$. The main basal cell (longest) $130\ \mu$. Receptacle $110–130\ \mu$ long; width at base $7.5\ \mu$, at apex about $45\ \mu$.

On abdomen of *Acylophorus pronus* Er., Massachusetts; *A. flavicollis* Sachs, Pennsylvania.

DICHOMYCES, nov. gen.

Receptacle flattened, bilaterally symmetrical, multicellular above a narrow stalk cell, terminated by two clearly defined transverse rows of cells: the sub-terminal cells of the lower row modified to form, anteriorly, single projecting tooth-like antheridia: the upper series bearing a pair of perithecia and several sterile appendages all symmetrically arranged. Appendages as in Peyritschiella, simple, cylindrical. Perithecia symmetrical.

This genus is closely allied to Peyritschiella from which it is distinguished by its bilateral symmetry and the constant presence of a pair of perithecia reaching maturity simultaneously. In the above description the term *anterior* is applied to the slightly convex side from which are produced the two short and sharp projections which are analogous to the single similar projection found in Peyritschiella, and represent highly developed single antheridia.

DICHOMYCES FURCIFERUS, nov. sp.

Receptacle consisting of a small basal cell, which is nearly hyaline distally and suffused with brown basally, the receptacle above gradually expanding into a more or less fan-like form, the basal portion wholly black and opaque, the opacity extending upwards externally and including a prong-like projection which extends above the base of the perithecium and terminates the sub-distal row of cells on either side; the latter, seven in number, becoming generally suffused with blackish brown, the long rectangular central cell usually more or less distinct, the remainder partly or wholly opaque and indistinguishable: the antheridia lighter brownish. The distal row of cells seven in number, their septa straight, thin, and clearly defined; the middle cell of the series bearing distally two appendages, placed antero-posteriorly, the terminal cells of the series on either side also bearing two appendages, the inner slightly anterior. Perithecia bent slightly forward, tapering very slightly to the blunt apex, which bears a short recurved tooth-like projection on either side. The perithecia and distal row of cells faintly purplish. Appendages short, simple, hyaline, cylindrical, with a constricted blackish base. Perithecia 63 × 16–18 μ. Receptacle: length to base of perithecia about 90 μ; to tips of external projections 100–120 μ; greatest width 55–60 μ.

On abdomen of *Philonthus debilis* Grav., Massachusetts.

A most singular plant looking like a two-pronged fork between the black arms of which arises the pair of perithecia. The lower portion of the receptacle is so opaque that the cell structure is indistinguishable.

PEYRITSCHIELLA NIGRESCENS, nov. sp.

Receptacle consisting of a single basal nearly hyaline cell, followed by three elongate sub-basal cells; the two outer suffused with blackish brown, externally opaque: above these follow two successive more or less irregular transverse rows of cells, the lower terminated on one side by a slight prominence close beside the sharp brownish projection (antheridium) characteristic of the genus, a single appendage also arising near the base of this projection. The upper distal row of cells, five in number, ending on one side in a small cell which bears a single appendage above the antheridium, while at the other end the series is terminated by a large cell forming a broad prominence indistinctly divided into about five small cells and bearing a group of four appendages. Appendages short, hyaline, cylindrical. Perithecia 65 × 19 μ. Receptacle 70 × 37 μ. Total length 130 μ.

On leg of *Philonthus debilis* Grav., Massachusetts.

This well marked species is easily separated from the two previously described by its blackish suffusions and the arrangement of its appendages. It is smaller even than *P. minimus*, and bears a superficial resemblance to *Dichomyces furciferus*.

Heimatomyces borealis, nov. sp.

Hyaline or slightly yellowish. Perithecium large and stout, its distal half or more free from the receptacle, tapering slightly to the large blunt apex. Sub-basal cell of the receptacle small and flattened: the distal portion of the receptacle composed of only three cells (the fourth obsolete or very minute), the distal one large, longer than broad, its base very oblique, the two others very long and subtriangular, the septum between them running obliquely from the insertion of the "trichogyne" nearly to the base of the inner cell. Perithecia 80–90 × 22 μ. Receptacle, total length 75–80 μ; length to tip of perithecium 110–120 μ.

On legs of a minute water beetle, Kittery, Maine.

This species differs from those previously described by the absence of the fourth cell in the distal portion of the receptacle. It is related to the succeeding species in its cell arrangement, but is easily separated by its greater size, the relative position and shape of the perithecia, etc. The ascogenic area is also external, a position which seems exceptional.

Heimatomyces Bidessarius, nov. sp.

Hyaline becoming faintly tinged with blackish. Perithecium small, its upper third or fifth free from the receptacle, the apex bent outwards, the basal portion straight, the tip broad with large prominent lips. Receptacle stout, the two basal cells more nearly equal, the two cells above these longer than broad and nearly equal; distal portion nearly as in *H. borealis*, the base of the short terminal cell horizontal. Perithecia 40–48 × 15 μ. Receptacle 65 μ long. Total length to tip of perithecium 80 μ.

On elytra of *Bidessus granarius* Aube, Kittery, Maine.

CERATOMYCES, Thaxter.

The six additional species of this genus, five of which are described below, represent a peculiar and well marked type. The two species

described as *C. furcatus* and *C. contortus*, together with a third related form as yet undescribed, differ from other members of the genus in the much smaller number of cells in each of the four cell rows composing the wall of the perithecium, although the number, which finds its maximum in *C. rostratus*, is also very greatly reduced in *C. miniscculus*. The spores of the two first mentioned species are also peculiar, in that the septum also divides the hyaline envelope. In all the species the trichogyne arises from the angle formed between the perithecium and the antheridial appendage. In a few specimens two perithecia arise side by side, each associated with an appendage; but this condition seems decidedly exceptional. It should be observed also that two species, *C. rostratus* and *C. capillaris*, are without the perithecial appendage peculiar to the remaining species.

Ceratomyces contortus, nov. sp.

Hyaline becoming very faintly brownish. Receptacle consisting of three superposed cells above which three cells form the general base of the perithecium and appendage. Perithecium long and slender, usually constricted at the base, slightly inflated and bent outwards, the apex pointed and curved. A short appendage arises sublaterally below the apex and is strongly curved, extending inwards beyond the apex, its fifth and sometimes also its sixth cell producing from its upper surface a stout branch which may be simple or may bear a few secondary branches at irregular intervals. Antheridial appendage consisting of about twelve superposed cells, producing a few branches from its inner side at irregular intervals, the branches in turn more or less irregularly branched. Spores 80–85 × 3–3.5 μ. Perithecia 200–260 × 35–45 μ. Receptacle about 125 μ long. Antheridial appendage 110–130 μ. Perithecial appendage 75 μ long.

On inferior surface of abdomen of *Berosus striatus* Say, Maine.

Ceratomyces furcatus, nov. sp.

Hyaline becoming more or less suffused with reddish brown, the appendages sometimes purplish. Receptacle composed of three or four superposed cells, surmounted by two cells from which arise the perithecium and appendage. Perithecium large and stout, externally nearly straight, inwardly inflated and strongly curved to the pointed apex below which arises externally and sublaterally a large stout flexed appendage, tapering and bearing towards its tip a single row of short branches which may be in turn once branched. Cell rows of perithe-

cium each consisting of about eight cells. Antheridial appendage very large, consisting of twenty cells (more or less) bearing branches at irregular intervals from its inner surface. Spores 85–90 × 4 μ. Perithecia 130–150 × 45–60 μ. Receptacle 90–110 × 45–55 μ. Antheridial appendage 300–425 μ. Perithecial appendage about 325 μ.

On inferior surface of thorax of *Berosus striatus* Say, Maine.

CERATOMYCES MINISCULUS nov. sp.

Becoming more or less deeply tinged with reddish brown. Receptacle consisting of about three superposed basal cells, all blackened opaque and indistinguishable, surmounted by a few small cells partly blackened below, from which arise the appendage and perithecium. Perithecium subconical, ten or eleven cells in each cell row, a short blunt conical unicellular projection borne sublaterally below the tip which is usually curved slightly outwards. Appendage tapering to a slender tip, simple, or bearing a few short branches near its apex, seldom as long as the perithecium. Spores 75 × 4 μ. Perithecia 110–150 × 30–40 μ. Receptacle, average, 90 × 40 μ. Appendage 50–110 μ long.

On the edge of the elytra of *Tropisternus nimbatus* Say, Maine, Connecticut, Texas.

CERATOMYCES FILIFORMIS, nov. sp.

Suffused with reddish brown. Receptacle consisting of three superposed cells, the basal one partly blackened, surmounted by two cells which form the origin of the perithecium and antheridial appendage. Perithecium very long and slender, nearly cylindrical, tapering abruptly and symmetrically to the subtruncate apex, the cell rows composed of very numerous cells (maximum forty five). Appendage short, tapering, straight, bearing terminally or subterminally one or two slender branches. Spores 55–60 × 3 μ. Perithecia 250–330 × 33–40 μ. Receptacle 35 × 85 μ. Appendage 90 μ.

On the edge of the elytra of *Tropisternus glaber* (Hb.) and *T. nimbatus* Say.

This species was at first taken for an abnormal form, but sufficient material shows that it is a well marked species. It occurs near the tip of the elytron, and is with difficulty distinguished from the bristle-like hairs among which it occurs. It is remarkable for the very small number of spores present in the perithecium.

Ceratomyces rostratus, nov. sp.

Reddish brown. Receptacle long, slender, expanding slightly upwards, consisting of about twelve superposed cells. Perithecium consisting of a clearly distinguished neck and an inflated oval basal portion, completely filled with spores and asci, which pushes the appendage to one side and continues directly the axis of the receptacle; the neck very elongate, irregularly cylindrical, its terminal portion at maturity abruptly bent upon itself, the recurved portion tapering slightly to the hunched asymmetrical apex: the cell rows made up of seventy cells, more or less. Appendage arising from a broad base flattened at maturity by pressure from the base of the perithecium consisting of about six superposed cells bearing numerous branches which may in turn be several times branched. Spores about 75 × 3.5 μ. Perithecia, basal portion, 110–150 × 65–90 μ; neck, including recurved portion, longest, 1.17 mm. Appendage about 90–100 μ long, its longest branches about 200 μ. Receptacle, large, about 260 μ long by 55 μ at the distal end.

On the inferior surface of *Hydrocombus fimbriatus* Melsh, Massachusetts, Texas; *Philhydrus cinctus* Say, Maine.

The most remarkable species of the genus, the enormously elongated neck of the perithecium becoming hooked only in fully mature specimens, and serving an evident purpose in the spore dissemination.

XI.

ON THE VARIATIONS OF THE "HALL EFFECT" IN SEVERAL METALS WITH CHANGES OF TEMPERATURE.

BY ALBERT L. CLOUGH AND EDWIN H. HALL.

Presented April 12, 1893.

THE variation of the so called "Hall effect" with change of temperature in the magnetic metals has long been known. In 1885 the following estimate was given: —

"A fall of 1° C. in temperature causes in the R. P. [rotational power] of Iron a fall of $\frac{3}{4}$% approx.

Steel, soft,	"	$\frac{1}{3}$	"
" tempered,	"	$\frac{1}{3}$	"
Cobalt	"	1	"
Nickel	"	$\frac{2}{3}$	"

Non-magnetic metals, apparently a small increase." *

The evidence in favor of an increase with fall of temperature in non-magnetic metals was very slight.

Leduc † has more recently studied the temperature change in bismuth.

The Hall effect shows itself in the form of an electromotive force, brought about by magnetic action, at right angles with the lines of flow of an electric current. It is evident that under such conditions the equipotential lines are no longer at right angles with the lines of flow, as they are when the magnetic force is not operating. This fact gives rise to the terms "rotational power" and "rotational coefficient," which have been used in describing the phenomena under discussion. These terms are somewhat ambiguous, for the reason that they may with as much propriety be used in connection with the rotation of the plane of polarization of light.

* E. H. Hall, Amer. Journ. of Sci., February, 1885, p. 133.

† La Lumière Electrique, Vol. XXIX., 1888.

arise from small cells cut off from the upper corners of the cells of the appendage, more commonly on the inner side, sometimes on both. Rarely a similar fertile branch may arise at the base of the appendage.

Rhadinomyces pallidus, nov. sp.

Hyaline becoming yellowish or faintly brownish. Perithecium elongate, distally subconical, bluntly pointed. Appendage consisting of three superposed cells, the distal bearing one to three or four stout tapering flexuous branches. Spores 50–55 × 3.5–4 μ. Perithecia 110–185 × 35–40 μ. Receptacle 37–55 × 20–30 μ. Primary appendage 50–200 μ, its branches (longest) 350–375 μ. Stalk of perithecium (larger) 90–110 × 25–30 μ.

On *Lathrobium punctulatum* Lec. and *L. angulare* Lec., Massachusetts. On *L. fulvipenne* Grav., Germany.

The European specimens of this species, though distinctly larger than the American, correspond in all essential characteristics. The receptacle may rarely produce three perithecia, two being not uncommonly present.

Rhadinomyces cristatus, nov. sp.

Perithecia nearly hyaline or slightly yellowish, blunt, tapering slightly, its stalk elongate. Appendage stout and long, its distal cell bearing a crest-like series of three to six or more dark reddish brown rigid, straight, erect, simple, cylindrical branches. One or more similar branches may also arise from the distal end of the middle cell of the receptacle. Spores 50 × 4 μ. Perithecium 110 × 32 μ; its stalk (longest) 280 × 19 μ. Receptacle (largest) 165 × 28 μ. Main appendage (largest) 185 × 19 μ; its branches (longest) 350 μ.

On *Lathrobium nitidulum* Lec., Kittery, Maine, and Cambridge, Mass.

CORETHROMYCES, Thaxter.

In addition to further material of the type species of this genus, several allied forms have been obtained, two of which are described below. Although these correspond in structure to the type, they furnish data which indicate that the limitation of the receptacle to the basal cells (apparently always two) from which the perithecium and the compound appendage were considered to arise directly, cannot be correct, from the fact that a second perithecium is not infrequently developed above the first from the basal cell of the supposed appendage. The main, usually black and opaque, portion of this structure

must therefore be considered the distal portion of the receptacle from which the appendages proper arise. The antheridia appear to be represented by certain short hyaline branches of the inner appendage, but their exact nature cannot well be made out from the dried material. The trichogyne is at first terminal and is well developed.

CORETHROMYCES CRYPTOBII, Thaxter.

Specimens occurring on *Cryptobium bicolor* Grav., from Pennsylvania, show that the mature perithecium is very elongate, exceeding the tips of the appendages by about half its length, subcylindrical, slightly inflated at the base, the apex abruptly conical, blunt symmetrical: borne on a stalk consisting of a single basal, two sub-basal, and a few small distal cells, on which the perithecium is seated. Perithecium $240 \times 38\ \mu$, its stalk $145 \times 26\ \mu$; basal cell hyaline brown at base, the remaining cells together with the perithecium reddish brown.

CORETHROMYCES SETIGERUS, nov. sp.

Perithecium yellowish, slender, slightly tapering, bluntly pointed: basal cell of stalk hyaline to its base, long; sub-basal cells squarish. Appendages arising from the distal and sub-distal cells of the receptacle, consisting of two or three rounded basal cells, which bear numerous long straight cylindrical septate deep brown branches, the whole curved slightly outwards and forming a crest-like structure. Receptacle consisting of five superposed cells, the four distal ones more or less rounded or squarish, deeply blackened externally, bent outwards at an angle of 45–60°, the perithecium with its stalk cells continuing directly the axis of the basal and sub-basal receptacle cells. Perithecia $110 \times 35\ \mu$. Spores (measured in perithecium) $30 \times 4\ \mu$. Total length of appendages $200\ \mu$ or more. Two basal cells of receptacle $35 \times 15\ \mu$. Total length from base to tip of perithecium 200–220 μ.

On thorax of *Lathrobium nitidulum* Lec., Massachusetts.

This is a much smaller species than *C. Cryptobii*, at once distinguished by its short primary and very long secondary appendages, the series of which recalls that of *Laboulbenia cristata*.

CORETHROMYCES JACOBINUS, nov. sp.

Perithecia (not fully mature) faintly brownish, nearly hyaline, tapering to a blunt apex. Appendages consisting of two more or less suffused basal cells, from which arise several stout branches them-

rounded prominence on one side; the third cell of the series is symmetrically expanded upwards, large and broad, more or less tinged with brown and surmounted by the circle of appendage bearing cells (about fifteen in number), which are more or less irregular in size and subtriangular in outline. The appendages consist commonly of a single large long slender flattened cell, its external surface bearing very numerous branches succeeding one another in a single vertical row, the lowest ones simple, beak-like, curved outwards; others higher up bearing beak-like branchlets, while certain of the upper branches may resemble the main cell from which they arise, and like them bear one or more terminal branchlets which may in turn be more or less copiously branched, the whole forming a dense tuft about the stalk of the perithecium of very complicated structure. Perithecia, one or two in number, arising from cells indistinguishable within the circle of appendages, straight, basally slightly inflated, distally subcylindrical and tapering abruptly to a symmetrical truncate apex; borne on a very elongate stalk which raises them far above the appendages and consists of a cylindrical very long basal cell terminated by three cells, one as long as and opposite the other two. Spores $40 \times 4\ \mu$. Perithecia $120–140 \times 22–26\ \mu$. Stalk (longest) $480\ \mu$. Appendages (longest) $185\ \mu$. The main basal cell (longest) $130\ \mu$. Receptacle $110–130\ \mu$ long; width at base $7.5\ \mu$, at apex about $45\ \mu$.

On abdomen of *Acylophorus pronus* Er., Massachusetts; *A. flavicollis* Sachs, Pennsylvania.

DICHOMYCES, nov. gen.

Receptacle flattened, bilaterally symmetrical, multicellular above a narrow stalk cell, terminated by two clearly defined transverse rows of cells: the sub-terminal cells of the lower row modified to form, anteriorly, single projecting tooth-like antheridia: the upper series bearing a pair of perithecia and several sterile appendages all symmetrically arranged. Appendages as in Peyritschiella, simple, cylindrical. Perithecia symmetrical.

This genus is closely allied to Peyritschiella from which it is distinguished by its bilateral symmetry and the constant presence of a pair of perithecia reaching maturity simultaneously. In the above description the term *anterior* is applied to the slightly convex side from which are produced the two short and sharp projections which are analogous to the single similar projection found in Peyritschiella, and represent highly developed single antheridia.

selves once or twice branched, the [...]
slightly, the inner members of the [...]
or less deeply suffused with brown. [...]
branches may also arise from the tip o[...]
Receptacle completely suffused and [...]
cell, which is hyaline with a basal b[...]
22 μ (not quite mature). Total len[...]
Two basal cells of receptacle 38 μ.
cium 150 μ or more.

On upper su[...]
fornia.

This species[...]
by its propor[...]
character of i[...]
veloped though[...]

[...] sp.

[...] is nearly hyaline
[...]ptacle above gradu-
[...] the basal portion
[...] upwards externally
[...] above the base
[...] of cells on either
[...]erally suffused with

Receptacle [...]
series of small[...]
the perithecia [...]
within which t[...]
or more in nu[...]
basal and thre[...]
superposed cel[...]
Spores as in o[...]

The dense [...]
obscures the h[...]
in this region [...]
in character f[...]
or sub-basal c[...]
corresponding [...]
of such cells. [...]
prove to be it[...]
sented by sho[...]

Receptacle [...]
slender, its up[...]
above it, whi[...]

On leg of *Philonthus debilis* Grav., Massachusetts.

This well marked species is easily separated from the two previously described by its blackish suffusions and the arrangement of its appendages. It is smaller even than *P. minimus*, and bears a superficial resemblance to *Dichomyces furciferus*.

Heimatomyces borealis, nov. sp.

Hyaline or slightly yellowish. Perithecium large and stout, its distal half or more free from the receptacle, tapering slightly to the large blunt apex. Sub-basal cell of the receptacle small and flattened: the distal portion of the receptacle composed of only three cells (the fourth obsolete or very minute), the distal one large, longer than broad, its base very oblique, the two others very long and subtriangular, the septum between them running obliquely from the insertion of the "trichogyne" nearly to the base of the inner cell. Perithecia 80–90 × 22 μ. Receptacle, total length 75–80 μ; length to tip of perithecium 110–120 μ.

On legs of a minute water beetle, Kittery, Maine.

This species differs from those previously described by the absence of the fourth cell in the distal portion of the receptacle. It is related to the succeeding species in its cell arrangement, but is easily separated by its greater size, the relative position and shape of the perithecia, etc. The ascogenic area is also external, a position which seems exceptional.

Heimatomyces Bidessarius, nov. sp.

Hyaline becoming faintly tinged with blackish. Perithecium small, its upper third or fifth free from the receptacle, the apex bent outwards, the basal portion straight, the tip broad with large prominent lips. Receptacle stout, the two basal cells more nearly equal, the two cells above these longer than broad and nearly equal; distal portion nearly as in *H. borealis*, the base of the short terminal cell horizontal. Perithecia 40–48 × 15 μ. Receptacle 65 μ long. Total length to tip of perithecium 80 μ.

On elytra of *Bidessus granarius* Aube, Kittery, Maine.

CERATOMYCES, Thaxter.

The six additional species of this genus, five of which are described below, represent a peculiar and well marked type. The two species

described as *C. furcatus* and *C. contortus*, together with a third related form as yet undescribed, differ from other members of the genus in the much smaller number of cells in each of the four cell rows composing the wall of the perithecium, although the number, which finds its maximum in *C. rostratus*, is also very greatly reduced in *C. miniscululus*. The spores of the two first mentioned species are also peculiar, in that the septum also divides the hyaline envelope. In all the species the trichogyne arises from the angle formed between the perithecium and the antheridial appendage. In a few specimens two perithecia arise side by side, each associated with an appendage; but this condition seems decidedly exceptional. It should be observed also that two species, *C. rostratus* and *C. capillaris*, are without the perithecial appendage peculiar to the remaining species.

Ceratomyces contortus, nov. sp.

Hyaline becoming very faintly brownish. Receptacle consisting of three superposed cells above which three cells form the general base of the perithecium and appendage. Perithecium long and slender, usually constricted at the base, slightly inflated and bent outwards, the apex pointed and curved. A short appendage arises sublaterally below the apex and is strongly curved, extending inwards beyond the apex, its fifth and sometimes also its sixth cell producing from its upper surface a stout branch which may be simple or may bear a few secondary branches at irregular intervals. Antheridial appendage consisting of about twelve superposed cells, producing a few branches from its inner side at irregular intervals, the branches in turn more or less irregularly branched. Spores 80–85 × 3–3.5 μ. Perithecia 200–260 × 35–45 μ. Receptacle about 125 μ long. Antheridial appendage 110–130 μ. Perithecial appendage 75 μ long.

On inferior surface of abdomen of *Berosus striatus* Say, Maine.

Ceratomyces furcatus, nov. sp.

Hyaline becoming more or less suffused with reddish brown, the appendages sometimes purplish. Receptacle composed of three or four superposed cells, surmounted by two cells from which arise the perithecium and appendage. Perithecium large and stout, externally nearly straight, inwardly inflated and strongly curved to the pointed apex below which arises externally and sublaterally a large stout flexed appendage, tapering and bearing towards its tip a single row of short branches which may be in turn once branched. Cell rows of perithe-

cium each consisting of about eight cells. Antheridial appendage very large, consisting of twenty cells (more or less) bearing branches at irregular intervals from its inner surface. Spores 85–90 × 4 μ. Perithecia 130–150 × 45–60 μ. Receptacle 90–110 × 45–55 μ. Antheridial appendage 300–425 μ. Perithecial appendage about 325 μ.

On inferior surface of thorax of *Berosus striatus* Say, Maine.

Ceratomyces miniscculus nov. sp.

Becoming more or less deeply tinged with reddish brown. Receptacle consisting of about three superposed basal cells, all blackened opaque and indistinguishable, surmounted by a few small cells partly blackened below, from which arise the appendage and perithecium. Perithecium subconical, ten or eleven cells in each cell row, a short blunt conical unicellular projection borne sublaterally below the tip which is usually curved slightly outwards. Appendage tapering to a slender tip, simple, or bearing a few short branches near its apex, seldom as long as the perithecium. Spores 75 × 4 μ. Perithecia 110–150 × 30–40 μ. Receptacle, average, 90 × 40 μ. Appendage 50–110 μ long.

On the edge of the elytra of *Tropisternus nimbatus* Say, Maine, Connecticut, Texas.

Ceratomyces filiformis, nov. sp.

Suffused with reddish brown. Receptacle consisting of three superposed cells, the basal one partly blackened, surmounted by two cells which form the origin of the perithecium and antheridial appendage. Perithecium very long and slender, nearly cylindrical, tapering abruptly and symmetrically to the subtruncate apex, the cell rows composed of very numerous cells (maximum forty five). Appendage short, tapering, straight, bearing terminally or subterminally one or two slender branches. Spores 55–60 × 3 μ. Perithecia 250–330 × 33–40 μ. Receptacle 35 × 85 μ. Appendage 90 μ.

On the edge of the elytra of *Tropisternus glaber* (Hb.) and *T. nimbatus* Say.

This species was at first taken for an abnormal form, but sufficient material shows that it is a well marked species. It occurs near the tip of the elytron, and is with difficulty distinguished from the bristle-like hairs among which it occurs. It is remarkable for the very small number of spores present in the perithecium.

Ceratomyces rostratus, nov. sp.

Reddish brown. Receptacle long, slender, expanding slightly upwards, consisting of about twelve superposed cells. Perithecium consisting of a [illegible] distinguished neck and an inflated oval basal portion [illegible] filled with spores and asci, which pushes the appendage [illegible] side and assumes [illegible] the axis of the receptacle; the [illegible] portion at ma-[illegible] tapering slightly [illegible] made up of seventy [illegible] arising from a broad base flattened at [illegible] consisting of [illegible] numerous branches which may in [illegible] Perithe-[illegible] recurved por-[illegible] long, its longest [illegible] long by 55 μ [illegible]

[illegible] Mass-[illegible]

[illegible] elongated [illegible] mature speci-[illegible]

XI.

ON THE VARIATIONS OF THE "HALL EFFECT" IN SEVERAL METALS WITH CHANGES OF TEMPERATURE.

By Albert L. Clough and Edwin H. Hall.

Presented April 12, 1893.

The variation of the so called "Hall effect" with change of temperature in the magnetic metals has long been known. In 1885 the following estimate was given: —

"A fall of 1° C. in temperature causes in the R. P. [rotational power] of Iron a fall of $\frac{1}{3}$% approx.

Steel, soft,	"	$\frac{1}{3}$	"
" tempered,	"	$\frac{1}{5}$	"
Cobalt	"	1	"
Nickel	"	$\frac{2}{3}$	"

Non-magnetic metals, apparently a small increase." *

The evidence in favor of an increase with fall of temperature in non-magnetic metals was very slight.

Leduc † has more recently studied the temperature change in bismuth.

The Hall effect shows itself in the form of an electromotive force, brought about by magnetic action, at right angles with the lines of flow of an electric current. It is evident that under such conditions the equipotential lines are no longer at right angles with the lines of flow, as they are when the magnetic force is not operating. This fact gives rise to the terms "rotational power" and "rotational coefficient," which have been used in describing the phenomena under discussion. These terms are somewhat ambiguous, for the reason that they may with as much propriety be used in connection with the rotation of the plane of polarization of light.

* E. H. Hall, Amer. Journ. of Sci., February, 1885.

† La Lumière Electrique, Vol. XXIX., 1888.

The existence of a transverse electromotive force under the conditions described might be accounted for in either of two general ways: 1st. The combined action of the main electric current and the magnetic force might be supposed to produce in the conductor a state of strain, giving it for the time being properties similar to those possessed by certain crystals, which do not conduct equally well in all directions. This might be called the *static* theory of the phenomenon, and one adopting it would expect the transverse effect to increase or decrease with the electric resistance of the conductor, that is, he would expect to see a fall of temperature accompanied by a diminution of the transverse effect, and *vice versa*. 2d. The transverse electromotive force might be regarded as the result of molecular or cellular motions, probably rotations, set up within the conductor by the magnetic force, and acting upon the main current of electricity in such a manner as to produce a *tendency* to deflection. This might be called the *kinetic* theory, and one holding it need not be surprised to find the transverse electromotive force independent of those temperature changes which affect electric resistance.

As most observations upon the temperature changes of the Hall effect had been confined to narrow limits, between 30° C. and 0° C., it seemed important to undertake a serious and extended investigation reaching through a much greater range of temperatures. This investigation is by no means completed, but some results of interest have already been attained. Most of the experimental work leading to these results was done by Mr. A. L. Clough, a graduate student, in the Jefferson Physical Laboratory of Harvard College during the academic year 1891–'92.

The substances used were, especially, soft cold-rolled steel and soft rolled nickel, but some few observations were made with carbon, copper, and phosphor-bronze. The general method of the experiments was similar to that which Professor Hall had used in previous investigations. The most important variations, which will presently be described, were those required by the use of high temperatures. The substances examined, with the exception of carbon, were in the usual shape of thin strips several centimeters long and about one centimeter wide, with narrow arms projecting at right angles with the sides. None of the work lays claim to great numerical exactness. It is a pioneer exploration rather than an accurate survey.

In some observations at moderate temperatures the same narrow water bath was used that was described in the American Journal of Science, Vol. XXIX. p. 118. A hot-air bath was used for tempera-

tures above the range of this device. It was formed of a narrow brass chamber arranged to be placed conveniently between the magnet poles. It was furnished with a funnel-shaped pipe extending downward, under which could be set a Bunsen gas-burner, and it was surmounted by a brass chimney to carry off the products of combustion. The height of the flame of the burner could be regulated so as to furnish any required amount of heated air, which circulated uniformly past the specimen to be examined. By shielding the gas flame from air currents and jacketing the outside of the bath with asbestos cloth a tolerably uniform temperature was attained. A high range thermometer was inserted into the air bath, with its bulb in close proximity to the specimen.

In many cases the change of electrical resistance with change of temperature was noted by means of observations on the magnitude of the difference of potential between the admission and exit ends of the strip under examination. These observations served to show directly that in nickel and steel at ordinary temperatures the temperature coefficient of the Hall effect is greater than the temperature coefficient of the electrical resistance.

The numbers given in this paper are, in most cases, not those actually observed, but have been derived from the actual observations by changes, usually slight, intended to make allowance for certain variations in the conditions of the experiments, such as fluctuations of the magnetic force or of the main current in the strip. The results reached with the various substances examined will now be given.

Copper.

From a sheet of thin commercial copper about 0.01 cm. in thickness an experimental strip was cut, which had the usual form with the exception that the side arms were made very long in order that their junctions with the galvanometer wires might lie outside the air-bath. In the table that follows, the first column, t, gives the temperature in degrees Centigrade; the second column, a, the reading of the instrument used to measure the magnetizing current; the third, θ, the readings of the tangent galvanometer used to measure the primary current through the copper strip; the fourth, H, the Hall effect deflections of the mirror galvanometer.

t	a	θ	H.
°		°	
23	36.9	66.8	3.2
210	36.3	66.4	2.9
Above 360	36.5	66.3	3.1

These observations show that no large change in the Hall effect is produced in copper by a rise of more than 300°, and leave it an open question whether any change is produced.

Phosphor-Bronze.

The Hall effect in a strip of this substance was about one half as large as in the copper just described, the thickness of the two strips being nearly the same. Mr. Clough found no increase of this effect in raising the temperature from 20° to 360°. He found the temperature coefficient of the electrical resistance of the specimen examined to be about .00045.

Cold-Rolled Steel.

A number of strips of this substance, about 0.016 cm. thick, mounted or supported in various ways, were tested. For satisfactory results at high temperatures it was found necessary to make the side branches long enough to extend outside the air bath. Otherwise very troublesome thermo-electric effects were likely to occur at the junctions with the wires leading to the mirror galvonometer. The following table gives, in divisions of the galvanometer scale, the results of the series of observations that ran through the widest range of temperature.

t	H.
°	
18	5.26
116	15.0
199	27.2
263	39.5
319	49 0

The second column assumes a constant value of the primary current in the strip, and a constant value, about 1400 c. g. s., for the strength of the magnetic field and for the magnetic induction per square centimeter through the steel.

Curve A in Figure 1 is plotted to correspond with the quantities just given, the abscissas representing temperatures and the ordinates values of the Hall effect. For comparison, curve *a*, Figure 1, is intended to show the relation of temperature to magnetic permeability in "Whitworth mild steel," with a constant value, 1500, for the magnetic induction per square centimeter through it. This curve is plotted from data obtained from curves given by Dr. John Hopkinson in the Transactions of the Royal Society for 1889. It will be seen that the permeability curve of the Whitworth steel is concave upward, even

at very high temperatures, while the Hall effect curve, *as here given*, for French cold rolled steel begins to diminish in steepness in the region of 300° C. The data for the latter curve, however, are too inaccurate to warrant attaching much importance to this feature. It is very likely that the true curve would continue to increase in steepness far beyond the point corresponding to 300° C. It is evident that, until very high temperatures are reached, the Hall effect in French cold-rolled steel increases much more rapidly with rise of temperature than the permeability of Whitworth steel does.

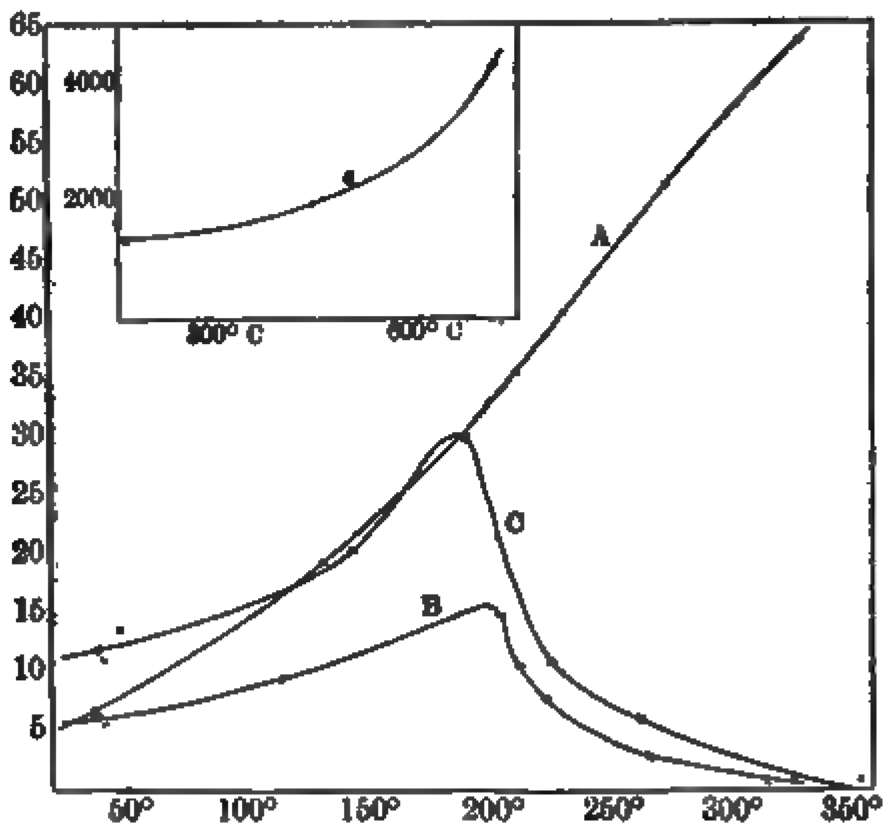


FIGURE 1.

NICKEL.

This was from a sheet of rolled nickel from Wharton, Philadelphia, and was probably very pure. It was about 0.033 cm. thick. The sheet from which it was cut was not large enough to allow of making the original side arms of the strip very long, but they were pieced out with shreds from the nickel sheet, so that the junctions of nickel with the copper wires lay outside the air bath. The shreds of nickel were fastened to the arms of the strip by means of screw-clamps, and these clamps were insulated from the nickel by pieces of mica. At times the device of wrapping the nickel strip in asbestos paper was tried as a means of preventing sudden fluctuations of temperature. In spite

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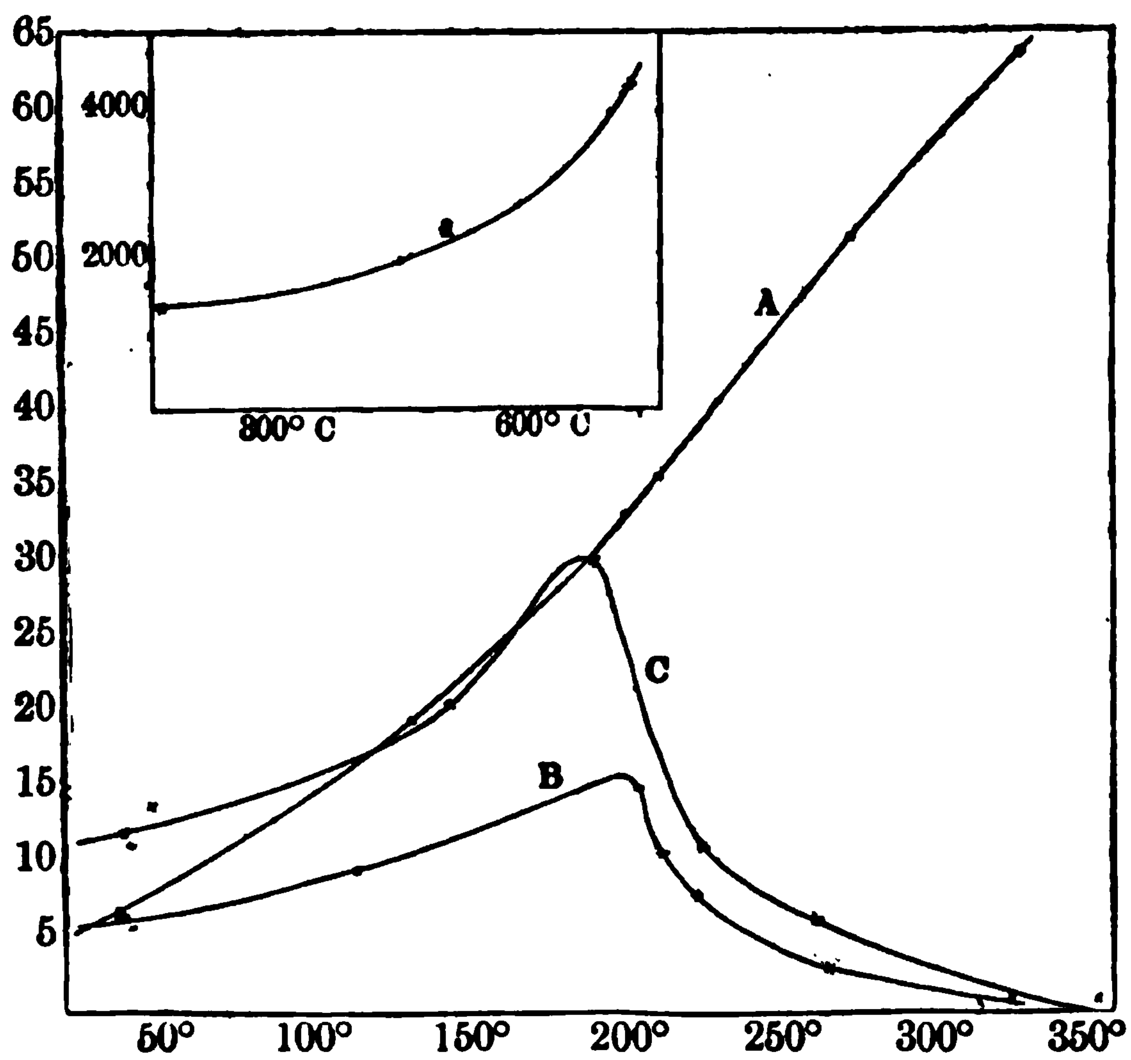

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of all precautions, however, there were large thermo-electric effects. Sometimes these effects were sufficiently large and sufficiently constant to carry the index of the mirror galvanometer completely off the scale and hold it there. In such cases a compensating arrangement was resorted to, which consisted of a short wire inserted in the galvanometer circuit, which wire formed also part of another circuit containing a Daniell cell and a variable resistance. This arrangement tended to send through the galvanometer a small current, which was made to oppose and nearly neutralize the thermo-electric current from the nickel strip. There were, nevertheless, serious fluctuations of the galvanometer index when high temperatures were used, and at the highest temperatures, where, it will be observed, the Hall effect in nickel was very small, it was necessary to take a long series of readings in order to obtain a result even approximately satisfactory. The following table shows the results arrived at, the Hall effects being expressed as before, in divisions of the galvanometer scale.

Strength of Field = 1,500 c g s.		
Date.	t °C.	H.
April 27, 1892	18	6.2
May 6, "	22	5.8
" 6, "	98	9.5
" 6, "	192	14.9
" 7, "	22	6.2
" 9, "	211	7.9
" 9, "	257	2 9
" 9, "	305	0.8
" 9, "	200	10 7
" 9, "	316	0.9
" 10, "	20	6.4

Strength of Field = 3,000 c. g. s		
Date.	t °C.	H.
May 10, 1892	20	12.0
" 12, "	22	11.1
" 12, "	128	20.4
" 12, "	213	11.0
" 16, "	252	6.2
" 17, "	345	1.0
" 18, "	29	13.8
" 18, "	177	30.0
" 18, "	345	—1.5

The observations now recorded for nickel have been used in plotting the curves B and C in Figure 1. The nickel strip was, like the steel strip, so thin that the magnetic induction per square centimeter through it is assumed to have been the same as the strength of the field in which the strip was placed. Accordingly, the value of the magnetic induction is constant for each curve. The abscissas represent temperatures and the ordinates represent Hall effects. These ordinates for the nickel curves are reduced to the same scale as those for the steel curve; that is, the curves are an attempt to show how the Hall effects in nickel, with magnetic inductions 1500 and 3000, would compare in magnitude with those in steel, with magnetic induction 1400, if the strips were of the same dimensions and carried the same primary current.

Both of the nickel curves increase in steepness at first, but attain a maximum height between 150° and 200° and then fall very rapidly.

It is well known that certain marked changes occur in two of the physical properties of nickel in the region of 200° C. One of these is a thermo-electric effect, a reversal of the so called "specific heat of electricity" in the substance; the other is a great diminution of the magnetic permeability.

The "specific heat of electricity" is supposed to be nearly constant at temperatures below 200° C., and to suffer a second reversal of sign at a point somewhat above 300° C., in which two particulars it appears to have no connection with the course of the Hall effect at the same temperatures.

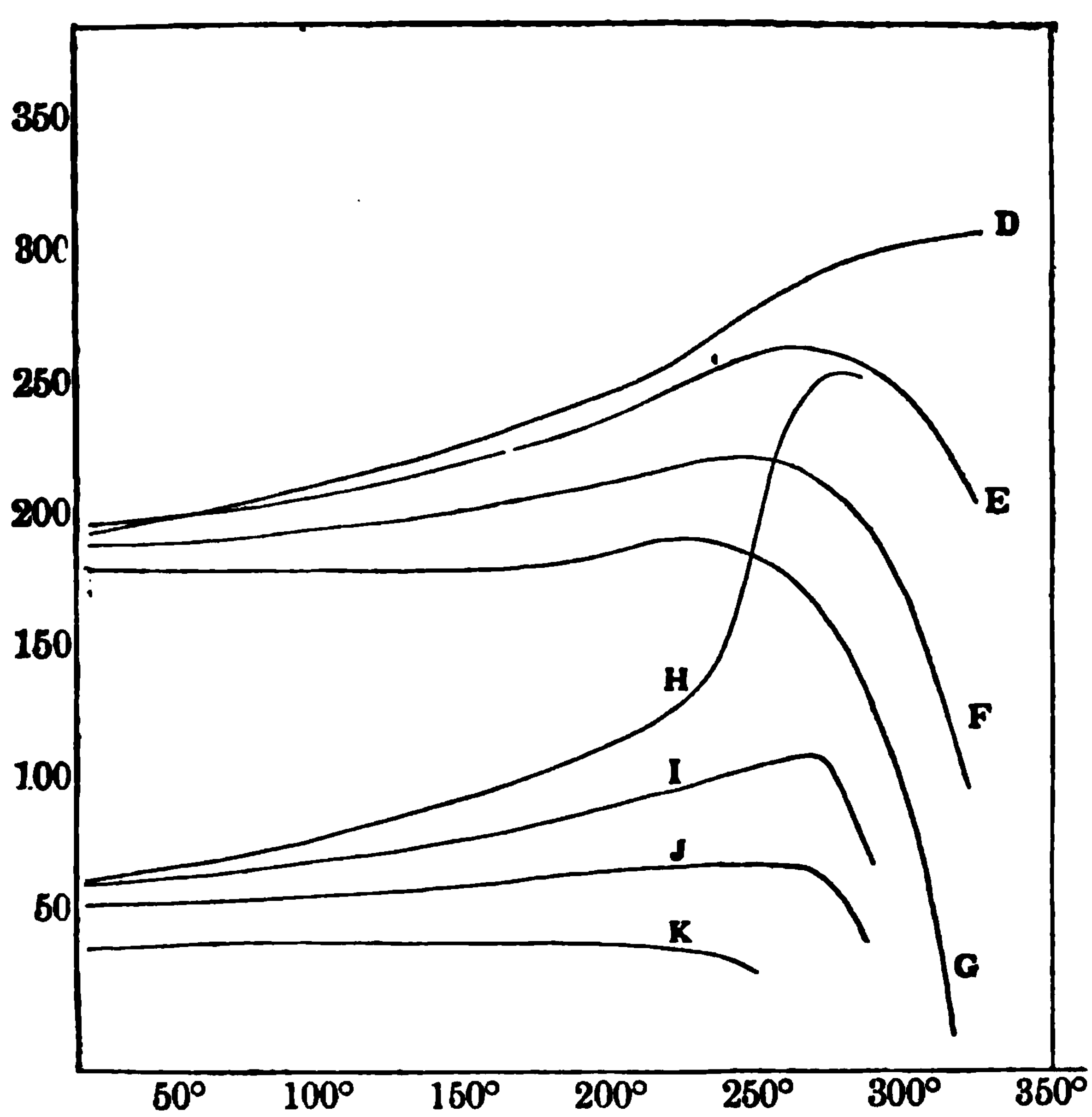

FIGURE 2.

In Figure 2 several curves are given to illustrate the changes of magnetic permeability, with unchanging magnetic induction, which nickel suffers with rise of temperature. Curves D, E, F, and G are plotted with data taken from the curves given by Mr. C. A. Perkins in the American Journal of Science, Vol. XXX. p. 218, to show how the magnetic properties of very pure rolled nickel are affected by changes of temperature. None of the curves given by Mr. Perkins

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Curve.	Magnetic Induction.
B (Fig. 1.)	1,500
C "	3,000
D	1,500
E	2,000
F	2,500
G	3,000
H	500
I	1,000
J	1,500
K	2,500

An examination of curves D to K shows certain general resemblances. Most of these curves grow steeper with rising temperature, until a point lying between 200° and 250° is reached, then continue to ascend with diminishing steepness, and, attaining a maximum height before 300° is reached, afterward plunge suddenly downward. A similar statement holds true of the Hall effect curves B and C, as we have seen, but the turning points occur at considerably lower temperatures.

Some of the permeability curves in Figure 2 seem likely to cross the base line at temperatures between 300° and 400°, but experiment gives no warrant for such crossing, and there is much evidence in favor of continuing them as asymptotes to the base line. Curves B and C are probably asymptotic to the base line, although further experiments upon this point would not be superfluous.

In the group of curves D to G, as in the group H to K, it is evident that an increase of magnetic induction is accompanied by a lowering of the temperature of maximum permeability. In curves B and C it

appears that an increase of magnetic induction is accompanied by a lowering of the temperature of maximum Hall effect, but the number of observed points from which curve B is plotted is too small to warrant a conclusion upon this particular.

SUMMARY.

The Hall effect in copper and in phosphor-bronze is affected but little, if at all, by a rise of temperature from 20° to 360° C.

The Hall effect was about one half as great in the phosphor-bronze examined as in the copper, under like conditions.

The temperature coefficient of the electrical resistance of the phosphor-bronze appeared to be about 0.00045.

The Hall effect was observed in battery carbon.

In nickel there is on the whole, in spite of certain marked differences, a strong resemblance between the temperature changes of magnetic permeability and the temperature changes of that "rotative power" upon which the Hall effect depends. It is doubtful whether an equally strong resemblance as to temperature changes could be made out between either of these properties and any other property of nickel. An equally broad statement cannot as yet be made concerning iron or steel, but the evidence obtained, so far as it goes, is on the whole in favor of such a proposition.

NOTE. — ADDED MAY 19, 1893.

Wiedemann's Annalen, No. 3, 1893, contains an "Explanation of the Hall Phenomenon," by E. Lommel, which seems to me not well considered. Without reproducing Lommel's argument, which is easily accessible, I will make the following criticisms.

1. The "explanation" attributes to the supposed Amperian currents at the boundary of a magnetized body an entirely new power, in assuming them to increase the strength of an ordinary electric current within one half of the body and to decrease it in the other half.

2. If the Amperian currents in the boundary had the supposed effect upon the distribution of the current within the body, it is very doubtful whether this would produce the Hall phenomenon.

3. Lommel's conclusion is that the Hall effect has one direction in magnetic metals, and the opposite direction in diamagnetic metals. In fact, the direction in iron is opposite to that in nickel.

E. H. H.

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Wiedemann's Annalen, No. 6, 1893, contains an interesting and important article by Professor Kundt on the "Hall Phenomenon in Iron, Cobalt, and Nickel." Taking exceedingly thin, transparent films of these metals, and subjecting them to the action of a magnetic field varying from a moderate intensity up to a value between 21,000 and 22,000 c. g. s., he has, with each metal, found the Hall effect and the rotation of the plane of polarization of light to maintain a constant ratio to each other throughout the whole range of magnetization. Then, depending upon the work of Du Bois (Wied. Ann. 31, 1887) for proof that the rotation of the plane of polarization of light in these metals is proportional to the *magnetization* ($\mathfrak{J}$) as distinguished from the *magnetic induction* ($\mathfrak{B}$), he concludes that in any given plate of iron, cobalt, or nickel the Hall effect is, other things being equal, proportional to the magnetization.

Professor Kundt credits me with having been the first to show the probability of a close connection between magnetization proper and the Hall effect in the case of nickel, but states that, in the case of iron and cobalt, "investigations hitherto have not gone beyond the limits within which the magnetization remains proportional to the magnetizing force." In this statement I think he does scant justice to some experiments of mine published in the American Journal of Science for August and October, 1888. These experiments, although they did not go far enough to put the matter absolutely beyond question, I felt to warrant me in making and publishing the following inference: "When a piece of iron, cobalt, or nickel is made to approach the state of 'magnetic saturation,' the transverse current [Hall effect] obtained from it increases somewhat less rapidly than the magnetic induction through the metal, but experiments with very highly magnetized iron and nickel indicate that this transverse current tends toward a fixed limit rather than a maximum followed by a decline."

The validity of Professor Kundt's conclusion that the Hall effect is *strictly proportional* to the magnetization, depends upon the validity of the law which Du Bois, as already stated, announced concerning the relation between magnetization and rotation of the plane of polarization of light. Now as this law was obtained by assuming for the thin transparent films of "galvanoplastic" nickel and cobalt used by Du Bois, the same magnetic coefficients found by Rowland in his famous rings of cast nickel and cobalt, and as, moreover, with this

assumption, the accordance between the calculated magnetizations and the observed rotations is far from strict, the law announced by Du Bois cannot be regarded as established beyond question.

If the law of Du Bois is strictly true, the strict proportionality between Hall effect and magnetization announced by Kundt must be held subject to the condition, *at a given temperature.* For numerous experiments, of which those in the paper to which this note is appended are the most extensive, have shown the Hall effect in the magnetic metals at ordinary temperatures to increase rapidly with rise of temperature, much more rapidly than the *magnetization* can be supposed to increase under the same conditions. In a very thin sheet of metal the relation between magnetization ($\mathfrak{I}$), permeability (μ), and intensity of magnetic field (which I will call F, and which in the case considered is practically equal to $\mathfrak{B}$, the magnetic induction) is $\mathfrak{I} = \frac{(\mu - 1)\, F}{4\, \pi\, \mu}$. Now when μ is much greater than unity, as it is in all the magnetic metals at ordinary temperature and moderate magnetizations, it is evident that $\mathfrak{I}$ increases with rise of temperature much less rapidly than μ does. As to the rate at which μ increases with rise of temperature in the metals examined by Mr. Clough and myself, there is considerable doubt, but it is simply *impossible* for it to be great enough to make the magnetization $\mathfrak{I}$ keep pace with the Hall effect in the changes observed. The value of $\mathfrak{I}$ when $\mu = 20$ is $\frac{19}{80} \times \frac{F}{\pi}$. Its value when $\mu = \infty$ is $\frac{1}{4} \times \frac{F}{\pi}$. Such considerations as this have forced me to abandon the hope, which I once entertained, of making out for the relation between Hall effect and magnetization a law as simple as that which Professor Kundt has announced. It has long seemed, and still seems, to me that the only satisfactory method of studying that whole matter will be to repeat Rowland's experiments with carefully prepared rings from carefully chosen material, and then to work down slices of the same material to the proper shape and dimensions for exhibiting the Hall effect.

E. H. H.

These observations show that no large change in the Hall effect is produced in copper by a rise of more than 300°, and leave it an open question whether any change is produced.

Phosphor-Bronze.

The Hall effect in a strip of this substance was about one half as large as in the copper just described, the thickness of the two strips being nearly the same. Mr. Clough found no increase of this effect in raising the temperature from 20° to 360°. He found the temperature coefficient of the electrical resistance of the specimen examined to be about .00045.

Cold-Rolled Steel.

A number of strips of this substance, about 0.016 cm. thick, mounted or supported in various ways, were tested. For satisfactory results at high temperatures it was found necessary to make the side branches long enough to extend outside the air bath. Otherwise very troublesome thermo-electric effects were likely to occur at the junctions with the wires leading to the mirror galvonometer. The following table gives, in divisions of the galvanometer scale, the results of the series of observations that ran through the widest range of temperature.

t	H.
°	
18	5.26
116	15.0
199	27.2
263	39.5
319	49 0

The second column assumes a constant value of the primary current in the strip, and a constant value, about 1400 c. g. s., for the strength of the magnetic field and for the magnetic induction per square centimeter through the steel.

Curve A in Figure 1 is plotted to correspond with the quantities just given, the abscissas representing temperatures and the ordinates values of the Hall effect. For comparison, curve a, Figure 1, is intended to show the relation of temperature to magnetic permeability in " Whitworth mild steel," with a constant value, 1500, for the magnetic induction per square centimeter through it. This curve is plotted from data obtained from curves given by Dr. John Hopkinson in the Transactions of the Royal Society for 1889. It will be seen that the permeability curve of the Whitworth steel is concave upward, even

at very high temperatures, while the Hall effect curve, *as here given*, for French cold rolled steel begins to diminish in steepness in the region of 300° C. The data for the latter curve, however, are too inaccurate to warrant attaching much importance to this feature. It is very likely that the true curve would continue to increase in steepness far beyond the point corresponding to 300° C. It is evident that, until very high temperatures are reached, the Hall effect in French cold-rolled steel increases much more rapidly with rise of temperature than the permeability of Whitworth steel does.

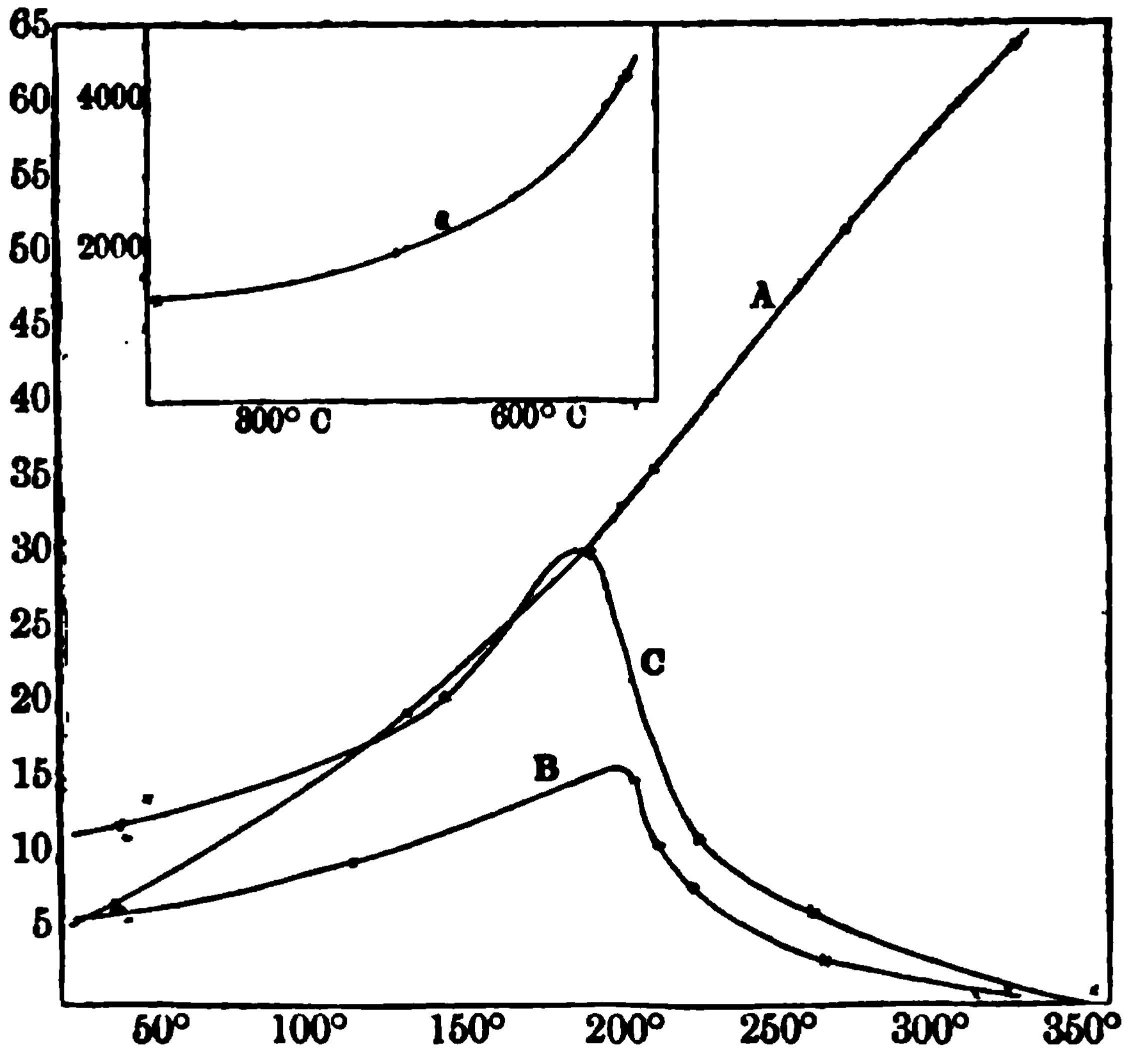

FIGURE 1.

NICKEL.

This was from a sheet of rolled nickel from Wharton, Philadelphia, and was probably very pure. It was about 0.033 cm. thick. The sheet from which it was cut was not large enough to allow of making the original side arms of the strip very long, but they were pieced out with shreds from the nickel sheet, so that the junctions of nickel with the copper wires lay outside the air bath. The shreds of nickel were fastened to the arms of the strip by means of screw-clamps, and these clamps were insulated from the nickel by pieces of mica. At times the device of wrapping the nickel strip in asbestos paper was tried as a means of preventing sudden fluctuations of temperature. In spite

of all precautions, however, there were large thermo-electric effects. Sometimes these effects were sufficiently large and sufficiently constant to carry the index of the mirror galvanometer completely off the scale and hold it there. In such cases a compensating arrangement was resorted to, which consisted of a short wire inserted in the galvanometer circuit, which wire formed also part of another circuit containing a Daniell cell and a variable resistance. This arrangement tended to send through the galvanometer a small current, which was made to oppose and nearly neutralize the thermo-electric current from the nickel strip. There were, nevertheless, serious fluctuations of the galvanometer index when high temperatures were used, and at the highest temperatures, where, it will be observed, the Hall effect in nickel was very small, it was necessary to take a long series of readings in order to obtain a result even approximately satisfactory. The following table shows the results arrived at, the Hall effects being expressed as before, in divisions of the galvanometer scale.

STRENGTH OF FIELD = 1,500 c g s.

Date.	t °C.	H.
April 27, 1892	18	6.2
May 6, "	22	5.8
" 6, "	98	9.5
" 6, "	192	14.9
" 7, "	22	6.2
" 9, "	211	7.9
" 9, "	257	2.9
" 9, "	305	0.8
" 9, "	200	10 7
" 9, "	316	0.9
" 10, "	20	6.4

STRENGTH OF FIELD = 3,000 c. g. s

Date.	t °C.	H.
May 10, 1892	20	12.0
" 12, "	22	11.1
" 12, "	128	20.4
" 12, "	213	11.0
" 16, "	252	6.2
" 17, "	345	1.0
" 18, "	29	13.8
" 18, "	177	30.0
" 18, "	345	—1.5

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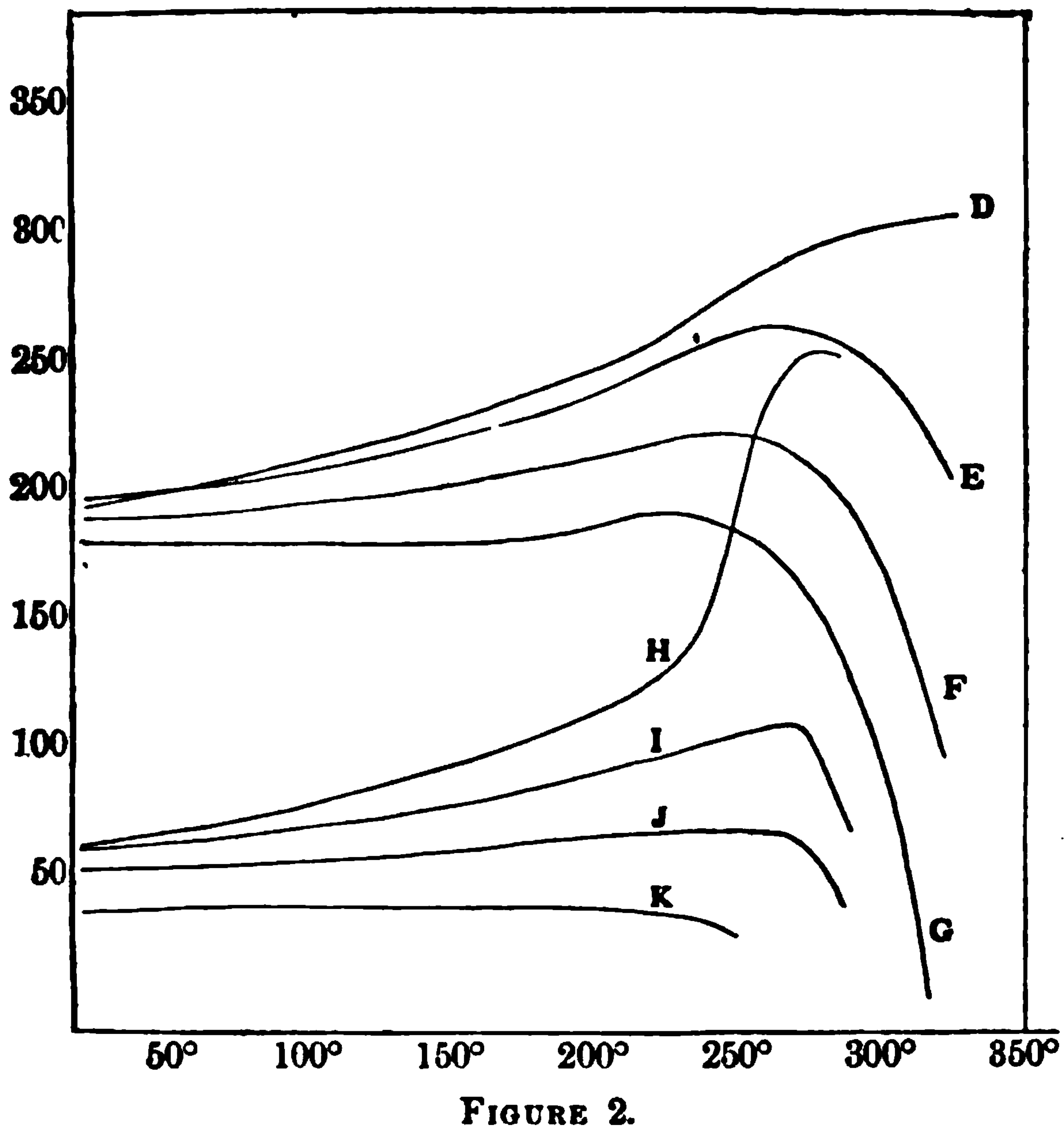

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E. H. H.

XII.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

ON THE OCCLUSION OF GASES BY THE OXIDES OF METALS.

By Theodore William Richards and Elliot Folger Rogers.

Presented May 10, 1893.

In the course of an investigation upon the atomic weight of copper, recently conducted in this Laboratory, it was noted that cupric oxide prepared by the ignition of the nitrate always contains a considerable amount of occluded gas, which is composed mainly of nitrogen.* Cupric oxide prepared from the carbonate, on the other hand, appears to possess no such property of occluding gases. Since the material used by Hampe and others had all been made by the former method, it was at once evident that the occluded gas contained in the oxide was wholly responsible for the formerly accepted erroneous results for the atomic weight of copper.

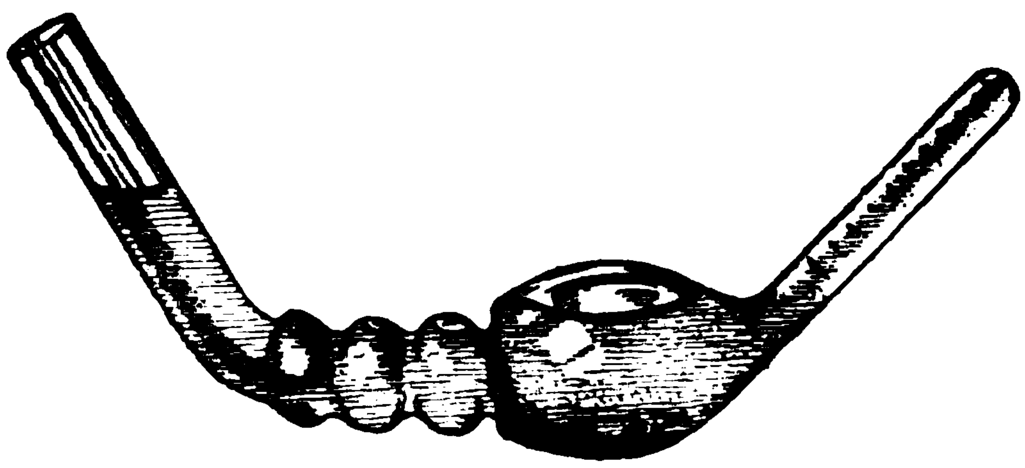
The results of these experiments suggested the possibility that gases might be occluded by all oxides prepared in this way from the nitrates. It became a matter of much importance to test the point, for such oxides have often furnished the starting point for determinations of atomic weights.

The method adopted in the present research was precisely similar to that used in the case of the cupric oxide. Since it is by no means certain that indefinite heating in a vacuum could drive out all the gas from the compact, often crystalline compound under examination, the material was dissolved in acids under such conditions that the gas set free could be measured and analyzed.

The simple apparatus needed has been described and explained in the paper already quoted. The material to be investigated was placed

* Theodore W. Richards, These Proceedings, XXVI. 281. In 1868 Frankland and Armstrong pointed out this fact; but their statement lacked definiteness, and has since been largely forgotten.

in the largest bulb of the bulb-tube shown in the accompanying diagram, and the tube was about half filled with cold water which had been thoroughly boiled. The whole was then connected with the water pump, and freed from adhering air bubbles by agitation in the partial vacuum, — the water being allowed to boil gently under the reduced pressure. Subsequently, the tube was filled with boiled water, and returned to its normal horizontal position. Pure acid was now run in from a pipette, a short piece of glass rod within the large bulb furnishing a means of agitating the oxide during its solution. The gas which was set free was finally collected and measured in the sealed end of the apparatus. In the concluding experiments, where greater accuracy was desired, the gas was transferred, and remeasured in a tube which had been carefully calibrated by means of mercury.



The gas was analyzed with the help of a small Hempel's apparatus made for the purpose. The burette with which the first ten analyses were made was about seven millimeters in internal diameter and could be read to a fiftieth of a cubic centimeter, while that used for the later analyses was only four millimeters in diameter and could be read with reasonable certainty to the hundredth. The portion of the gas absorbed by caustic potash was assumed to be carbon dioxide, and the further portion which was absorbed by alkaline pyrogallol was assumed in like manner to be oxygen. The residue was perfectly inert, and was undoubtedly nitrogen. One sample of this residue obtained from zincic oxide, was mixed with oxygen and subjected to the spark of an induction coil, without diminution in volume. The apparatus and chemicals were tested from time to time by analyses of air.

In every case, the gas while saturated with aqueous vapor was measured at the ordinary temperature and atmospheric pressure of the room. The variations from the mean values of 22° and 76.0 centimeters were not sufficient to need attention in crude work of this kind, when working upon such very small quantities of gas.

Zincic Oxide.

Preliminary experiments with this substance gave results exactly corresponding to those obtained from cupric oxide. If the substance was prepared by ignition of the nitrate, very considerable amounts of gas were found to be occluded; while material of a similar grade of purity in every other respect made by heating zincic carbonate appeared to contain no trace of gas.

The oxide used in the first three experiments was made by treating so called pure zinc with nitric acid, evaporating to dryness, redissolving the zincic nitrate in water with the addition of a little nitric acid, precipitating a small amount of iron with ammonia in slight excess, evaporating the filtrate, and igniting the residue. This gave a faintly yellow oxide.

For the second series, a nearly neutral solution of fairly pure zincic chloride was precipitated while boiling by a solution of sodic carbonate. Part of the basic carbonate thus formed was ignited directly, the oxide thus produced containing no occluded gas (Experiment 4). The remainder was dissolved in nitric acid, evaporated to dryness, and ignited to the full heat of the blast lamp in an open porcelain crucible. Experiments 5, 6, and 7 are analyses of this yellowish sample.

For the third series a solution of "chemically pure" zincic nitrate was allowed to stand over an excess of zinc for some time. The filtered solution was evaporated until a portion of the nitrate had been converted into the basic salt. The whole was then poured into distilled water, and a solution of normal nitrate was thus obtained after the basic salt had been filtered off. This solution was treated a number of times with zincic hydrate, — which had been precipitated by ammonia and washed until free from the salts of this base, — and allowed to stand. The filtered solution was evaporated to dryness and heated in a porcelain crucible to about 240° C. over a ring burner. Part of this was analyzed at once (Experiment 8), part heated by a Bunsen burner (Experiments 9 and 10), and part ignited at a very high temperature in a Hempel clay furnace with the blast lamp and bellows (Experiments 11 and 12). Experiment 13 was made with a soft white oxide prepared from the basic nitrate.

Analyses 14 to 27 inclusive were made from oxide obtained as follows. Pure white zincic oxide of commerce was dissolved in nitric acid, and carefully washed zincic carbonate was added to this solution in slight excess. The whole was allowed to stand with occasional shaking for some time, and finally filtered and evaporated rapidly by

boiling. This gave a sample of the oxide which was very nearly white after intense heating in a double porcelain crucible.

In Experiments 22 and 23, pure oxygen was introduced into the flame of the blast lamp used for igniting the zincic oxide, the bottom of the outer crucible being melted where the flame struck it. The material analyzed in Experiment 22 was taken from the layer nearest to the zincic silicate formed in the bottom of the crucible by fusion of the glaze, and that used in Experiment 23 was taken from the top. The zincic oxide of Experiment 24 was heated to bright yellow heat in the same way. All the edges of the porcelain were rounded, and the cover and the crucible itself were fused to the heavy iron supports on which they rested. After twelve minutes the iron itself began to burn and the ignition was stopped. The oxide was found to be "sintered together," and was of a grayish color, as if it had been reduced in part. The inference was corroborated by the presence of zincic oxide on the cover of the crucible and on the sides of the stack of the furnace. The zincic oxide used in Experiment 25 was treated in a similar manner, but proved to be still darker in color. It was afterwards ignited for some time in an atmosphere of oxygen, in order that no reduced metal might be left.

The materials used in Experiments 26 and 27 were separate samples heated in a double crucible, with the cover of the inner crucible fitting inside the outer one, instead of covering both. This arrangement rendered less likely the entrance of reducing gases, and allowed freer play of air in the furnace. After the latter had been thoroughly heated by the ordinary blast lamp, oxygen was slowly turned on through a Y tube, to replace a large part of the air in the flame. This gave an intense white heat, which melted and burned the tip of a file in the fraction of a minute. In Experiment 27 the glaze of the inner crucible was fused, and the platinum which separated the two crucibles was cemented to the outer crucible. The crystalline residue of zincic oxide after this treatment was white with the faintest trace of yellow, but no sign of gray. As the crucible would not stand a higher heat, and as any quantitative determination could scarcely be carried on at a higher temperature, no attempt was made to push the heat further.

The fifth series of determinations was made with the object of discovering whether the trace of silica and alkali dissolved from the glass and porcelain might be responsible for the occlusion of the gases. First, a sample of the purest zinc that could be obtained was treated with a small amount of pure nitric acid in a porcelain dish, and the solution evaporated to small bulk in the presence of an excess of zinc.

Upon dilution the basic nitrate, which contained most of the impurities not deposited upon the zinc, was precipitated and removed by filtration. The solution was then evaporated to dryness and the residue ignited in porcelain. (See Experiments 28 and 29.) Another sample of zinc was dissolved in a similar way in platinum, and the resulting solution of the pure nitrate was divided into several portions. One portion was evaporated in glass and ignited in porcelain, the residue containing somewhat more gas than that which had been treated wholly in porcelain. (See Experiments 30, 31, 32, and 33.) Another part was evaporated and ignited in platinum (Experiment 34). This sample was undoubtedly reduced in part by the diffusion of gases from the flame.* Still another portion was ignited for a short time only in platinum, the ignition being completed in porcelain (Experiment 35). A fourth portion was ignited for a short time in an open platinum dish with free access of air (Experiment 36). Finally, the remainder of the solution of pure zincic nitrate was evaporated and ignited in a platinum vessel enclosed within one of porcelain. This specimen was not exposed to the action of reducing gases, and upon solution it evolved almost exactly the same amount of gas as the specimen which had been prepared in glass and ignited in porcelain. (See Experiments 37 and 38.)

Experiment 39, using zincic oxide prepared from the carbonate, was made to test again the accuracy of the method.

The weight of zincic oxide taken for each individual experiment is tabulated in the second column of the following table, and the third column indicates approximately the conditions used for the ignition of the different portions. The volume of gas given off on the subsequent solution of the zincic oxide in sulphuric acid is recorded in the fourth column, while the fifth contains the same data reduced to the standard of ten grams of zincic oxide. The sixth column contains a record of the analyses of the gases, and the seventh supplies information upon a few minor points connected with individual results.

* Erdmann, Pogg. Annal., LXII. 611. Morse and Burton, Am. Chem. Journ., X. 311-321.

No. of Exp.	Weight of Zincic Oxide.	Time and Temperature of Heating.	Volume of Gas evolved.	Volume of Gas calc. for 10 gr. of ZnO.	Analysis of Gas by Volume.	Remarks.
	grams.		c.c.	c.c.		
1	1.375	Blast lamp	1.6	12.0		
2	1.19	"	1.45	12.2		
3	1.225	"	1.53	12.5		
4	1.1	"	0.00	00.0		From carbonate.
5	1.05	"	2.1	20.		
6	1.08	"	2.1	19.4	$CO_2 = 2.0\%$ $O_2 = 55.5$ $N_2 = 42.5$	
7	1.075	"	2.15	20.		
8	1.27	240° C.	0.00	00.0		Gave test for nitrates.
9	1.005	Bunsen flame	.70	7.0		
10	1 065	"	.78	7.3		
11	1.22	Blast lamp Hempel furnace	.58	4.7		
12	1.91	"	.92	4.8		
13	1.05	Water blast Hempelfurnace	.20	1.9		Made from basic nitrate.
14	1.07	Water blast furnace 30 min.	.75	7.0		Fourth Series.
15	1.00	"	.71	7.1		
16	1.02	Blast	1.52	14.9	$CO_2 = 1.3\%$ $O_2 = 53.8$ $N_2 = 44.8$	
17	1.10	Water blast Furnace 2 hr.	.85	3.2	$O_2 = 9.1$ $N_2 = 90.9$	Partly reduced.
18	1.20	" 8½ "	1.12	9.1		18–21 heated in double crucible by water blast in furnace. Samples removed from time to time.
19	1.06	" 5 "	.83	7.8		
20	.85	" 6 "	.46	5.4		
21	.92	" 6½ "	.58	5.8		
22	1.07	Furnace 6½ hr. Oxygen flame, 15 min.	.42	3.9	$CO_2 = 0.0\%$ $O_2 = 16.9$ $N_2 = 83.1$	Layer next the silicate.
23	1.125	The same.	.48	4.3		Upper layer.

No. of Exp.	Weight of Zincic Oxide.	Time and Temperature of Heating.	Volume of Gas evolved.	Volume of Gas Calc. for 10 gr. of ZnO.	Analysis of Gas by Volume.	Remarks.
	grams.		c.c.	c.c.		
24	1.03	Oxy. fl. 15 min.	.24	2.3	$O_2 = 16.7\%$	Partially reduced and reoxidized.
25	1.105	" 30 "	.19	1.7	$N_2 = 83.3$	Reduced more than Ex. 24 and reoxid
26	.72	White heat 20 min.	.33	4.6	$CO_2 = 0$	White after ignition.
27	1.0125	White heat 35 min.	.45	4.4	$O_2 = 24\%$ $N_2 = 76$	" "
28	1.05	Water blast ½ hr.	.42	4.0		Fifth Series.
29	1.019	" 1½ "	.37	3 6		
30	1.34	Bunsen Flame 30 min.	.28	2.10		Probably contained nitric acid.
31	1 05	Water blast 30 min.	.97	9.2		
32	1.0035	Water blast 1 hr.	.68	6.8		
33	.9765	1½ hr.	.63	6.4		
34	1.03	Water blast ½ hr.	.175	1.7		Partially reduced.
35	1.08	½ hr.	.35	3.2		Less reduced.
36	1.50	20 min.	.82	5.46		Possibly reduced in part.
37	1.004	1½ hr.	.68	6 8		
38	1.018	2 hr.	.68	6.7		
39	1.00		0.00	0.00		Prepared from carbonate.

It is evident that we are dealing here with a phenomenon similar both qualitatively and quantitatively to that observed in the case of copper. Zincic oxide prepared from the nitrate occludes a very appreciable quantity of nitrogen and a somewhat variable quantity of oxygen. Continued application of heat tends to drive out both gases, the oxygen being less firmly held than the nitrogen; but the highest heat which we were able to obtain was insufficient wholly to eliminate either gas. Under like conditions, specimens of zincic oxide made from zincic nitrate which had been obtained in a number of different

ways appeared to hold approximately the same amounts of gas. It is almost, if not quite, impossible to prepare the oxide in this manner in a state wholly free from solid impurities taken from the containing vessel during the ignition of the purest possible zincic nitrate. The effort was made in the preceding series of analyses to prepare samples which must contain wholly different kinds of impurities. The fact that these different samples contained almost equal amounts of gas shows with reasonable certainty that the impurities are not responsible for the occlusion.

It is noticeable that the oxide obtained at a very low temperature, which still contained traces of zincic nitrate, contained little or no occluded gas (Experiments 8 and 30); also that six specimens which had been suspected of partial reduction contained much less gas than similar material free from this suspicion (Experiments 17, 24, 25, 34, 35, and 36).

Nickelous Oxide.

The series of experiments with nickelous oxide led to results not unlike those with zincic oxide. In this case sulphuric acid proved unsatisfactory as a solvent, and hydrochloric acid was adopted. A solution containing about twenty per cent of hydrochloric acid gas was freed from air by continued boiling, rapidly cooled, and run into the tube containing the oxide of nickel. On account of the very slow action of the cold acid the tube was warmed after exhausting the air as usual. The gas set free was measured as before.

In order to prove the accuracy of the method a gram of zincic oxide prepared from the carbonate was dissolved in hot hydrochloric acid in precisely a similar way. No trace of gas was evolved during this solution.

It was thought unnecessary to make a series of experiments as elaborate as that made with the zincic oxide. Nickelous nitrate was evaporated to dryness in porcelain and ignited fifteen minutes in a blast lamp and then a number of hours over a Bunsen burner in the furnace. (Analysis 1, below.)

A part of the nickelous oxide remaining was further ignited for two hours in the furnace by means of the water blast. This was used for the second analysis. A portion of the latter was ignited again in the furnace at the highest temperature we could obtain, by the addition of oxygen to the flame for about fifteen minutes, until the bottom of the outer crucible as well as the platinum foil between the two cru-

cibles was melted away. The arrangement of data in the table is similar to that already described.

No. of Exp.	Weight of Oxide.	Volume of Gas evolved.	Volume of Gas calc. for 10 gr. NiO.	Analysis of Gas by Volume.
	grams.	c. c.	c. c.	Per Cent.
1	1.14	.469	4.11	O_2 = 12.25 N_2 = 87.75
2	.997	.34	3.41	
8	1.13	.35	3.09	O_2 = 8.8 N_2 = 81.2

Magnesic Oxide.

The experiments with the oxide of magnesium led to very unexpected results, the amount of gas evolved upon the solution of this compound being five to twenty times as much as was obtained from zincic oxide, and over twenty-five times as much as from the oxide of nickel. More difficulty was found in decomposing the nitrate than before, and the remaining oxide was in a much harder and more compact state, and consequently more difficult to pulverize. The process used was similar to that employed in the case of the other oxides.

Magnesic nitrate made from pure nitric acid and magnesic carbonate of commerce was evaporated to dryness in porcelain. The residue was pulverized in an agate mortar, heated by means of the blast lamp in a covered porcelain crucible, and cooled over calcic chloride. For a parallel experiment, a portion of the original carbonate was converted into the oxide by simple ignition, the magnesia formed in this way evolving only an extremely small amount of gas upon solution (Experiment 2 below).

A third portion of magnesic nitrate was made from pure magnesium ribbon and pure nitric acid, and the oxide was obtained from this salt by evaporation and ignition in porcelain as usual (Experiment 7).

Sulphuric acid was used for the solution of the magnesic oxide, as in the case of zincic and cupric oxides. The following table explains itself.

No. of Exp.	Weight of Oxide used.	Temperature and Time of Heating.	Volume of Gas evolved.	Volume of Gas calc. for 10 gr. of MgO.	Analysis of Gas.	Remarks.
1	grams. .50	Blast lamp, 30 min.	5.45	109.	O_2 = 66.6% N_2 = 33.4	
2	about 1.0	" 1 hr.	.05	.5		Made from carbonate.
3	.50	" 1½ hr.	5.86	117.2	CO_2 = 5.98 O_2 = 53.7 N_2 = 40.29	Analyses made from one sample of oxide heated under different conditions. 1, 3, & 4 gave tests for nitrates with ferrous sulphate; 5 & 6 did not.
4	.25	" 2¼ hr.	2.81	92.4	O_2 = 47.6 N_2 = 52.4	
5	.25	" 3¼ hr.	2.31	92.4	CO_2 = 2.2 O_2 = 38.9 N_2 = 58.9	
6	.25	Oxygen blast, 20 min.	2.04	81.6	O_2 = 34.3 N_2 = 64.2 CO_2 = 1.5	
7	.25	Water blast, 1½ hr.	2.81	92.4		

The amount of gas occluded by magnesic oxide is thus far more than that occluded by the oxides of copper, zinc, and nickel. The quantities of carbon dioxide recorded in the table are undoubtedly far from accurate, since the gas was collected over water. It is interesting to note that the amount of nitrogen evolved by the oxide upon going into solution was slightly increased up to a certain point by the increasing time and heat of the ignition, while the amount of oxygen was rapidly diminished.

No. of Exp.	Volume of Nitrogen found in 1 gram of MgO.	No. of Exp.	Volume of Oxygen found in 1 gram of MgO.
	c.c. Gas.		c. Gas.
1	3.6	1	7.2
3	4.72	3	6.3
4	4.84	4	4.4
5	5.44	5	3.6
6	5.24	6	2.8

The Oxides of Cadmium, Mercury, Lead, and Bismuth.

These oxides, the only other suspected ones which could be easily analyzed by the method in hand, all yielded negative results. The oxide of cadmium was distinctly crystalline, and contained only the merest trace of gas. The oxides of mercury, lead, and bismuth obtained by the ignition of the corresponding nitrates also appeared to contain no occluded gaseous impurity.

Unfortunately, the oxides of antimony, iron, and a number of other metals, are not sufficiently soluble in acids to test with ease their power of occlusion by this method. It seems probable that interesting results might be obtained from them: hence in the near future other methods will be tried here, with the hope of determining if these oxides also occlude gaseous impurity.

Theoretical Considerations.

From the fact, observed with both copper and zinc, that oxides which still contain a trace of nitrates, as well as those made from the carbonate, retain no imprisoned gas, it is readily inferred that the decomposition of a trace of nitric acid is alone responsible for the impurity. It is natural that this last trace of nitric acid should be confined below the surface, whence the gases resulting from its ultimate decomposition would find it hard to escape. On this supposition it is not unnatural that zincic oxide which has been partly reduced, and hence somewhat disintegrated, should contain less occluded gas than that which has not been thus reduced. Moreover, since magnesic nitrate is harder to decompose than the other nitrates, and the oxide is more compact, we should expect to find more gas occluded in this case than in the others. All these inferences agree with the facts. The difference in the rate of expulsion of the oxygen and of the nitrogen is interesting, and less easy to explain.

The negative results observed with a number of metals lead one to conclude that the physical condition of the oxides in these cases was so porous that even the last traces of nitrogen were allowed to escape. Indeed, cupric and zincic oxide made from very finely divided basic nitrates, obtained from aqueous solution, contained much less gas than samples which were obtained in a more compact condition by the direct ignition of the normal nitrate. This fact shows how much depends upon physical conditions.

It must be borne in mind that the occlusion of gases noted in this

paper is a very different phenomenon from the retention of undecomposed oxides of nitrogen alluded to by Marignac,* Morse and Burton, and others. Nitrogen present in the state of gas could of course give no test with sulphanilic acid and naphthylamine, or any other test for oxidized nitrogen. It is evident that the phenomenon we are now studying, like the other just spoken of, may be a very serious cause of error in many of the published determinations of atomic weights; these would hence appear lower than their true value, because of the extra material which is calculated as oxygen.† Before any quantitative results obtained in this way can be accepted as authoritative, definite proof must be brought forward of the absence of this source ot error. It is to be hoped that the able experimenters who have recently worked upon zinc, nickel, magnesium, and similar metals, have preserved typical specimens of their final products. If this is the case, nothing could be easier than to determine the amount of occluded gas, if any is present, and to apply the necessary correction.

As long ago as 1887 one of us was engaged, through the suggestion of Professor Cooke, upon an investigation of the atomic weight of zinc depending upon the analysis of zincic bromide. The work was discontinued because of the many publications upon this subject which appeared before it could be completed. Since the results recorded in this paper appear to indicate that the last word has not yet been said upon the subject, the investigation of zincic bromide and chloride is now being continued in this Laboratory.

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* "Il est probable que l'oxyde de zinc et la magnésie ne sont pas les seuls oxydes qui retiennent aussi énergiquement des composés nitreux, lorsqu'on les prépare par la calcination de leurs azotates." — Annales de Chemie et de Physique, Series [6], Vol. I. p. 311, foot-note.

† The following are the metals whose atomic weights have been determined by means of the oxide made through action of nitric acid: Hydrogen (cupric oxide), Magnesium, Aluminium, Vanadium, Manganese, Nickel, Cobalt, Copper, Zinc, Gallium, Selenium, Tin, Antimony, Tellurium. See Meyer and Seubert, Atomgewichte, pp. 17 to 42. Also Nickel, Krüss, Z. anorg. Chem., II. 235. Zinc, Morse and Burton, Amer. Chem. Journ., X. 311-321. Magnesium, Burton and Vorse, Chem. News, LXII. 267.

XIII.

ON REAL ORTHOGONAL SUBSTITUTION.

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§ 1. REAL PROPER ORTHOGONAL MATRICES.

1. IN a paper to appear in a forthcoming number of the "Quarterly Journal of Mathematics" I have shown that, if ϕ is any real proper orthogonal matrix, then, for a proper choice of the real skew symmetric matrix θ, we may put $\phi = e^{\theta}$, where e^{θ} denotes the exponential series $\Sigma_r \frac{\theta^r}{r!}$, which is convergent for any matrix. This theorem was published in these Proceedings, Vol. XXVI. It follows immediately from this theorem that any real orthogonal matrix whatever is given by the expression

$$\omega \left(\frac{1 - \Upsilon}{1 + \Upsilon}\right)^2,$$

for a proper choice of the real skew symmetric matrix Υ and of the matrix ω whose constituents are all zero except those in the principal diagonal which are severally equal to ± 1. The second factor in the above expression is the square of Cayley's expression for an orthogonal matrix.

If the determinant of the orthogonal matrix is equal to unity, we may put $\omega = 1$; if the determinant is equal to -1, and if at the same time unity is a latent root of even multiplicity,* we may put $\omega = -1$.

I shall show in this section that, as a consequence of the exponential representation of real proper orthogonal matrices, any such matrix may be represented by the square of Cayley's expression; and in § 2 it will be shown that the general theorem given above follows as a consequence of the theorem just stated.

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* If unity is not a latent root of the orthogonal matrix, its multiplicity is zero.

2. Let ϕ be a real proper orthogonal matrix, then by the theorem above referred to we may put

$$\phi = e^{\theta},$$

where θ is a real skew symmetric matrix.

Since θ is skew symmetric, its latent roots occur in pairs opposite in sign; that is, if H is a latent root of θ, then $-H$ is also a latent root of θ having the same multiplicity as H; since θ is skew symmetric and real, its latent roots are purely imaginary.*

It may be that among the latent roots of θ are integer multiples of $2\pi\sqrt{-1}$; in this case a real skew symmetric matrix θ_1 can always be found of which no integer multiple of $2\pi\sqrt{-1}$ is a latent root, and such that

$$\phi = e^{\theta} = e^{\theta_1}.$$

Thus, let the latent roots of θ be given by the following schedule:

Latent root,	$h_0 = 0$	$\pm h_1\sqrt{-1}$	$\pm h_2\sqrt{-1}$	....
Multiplicity,	m_0	m_1	m_2	....

Latent root,	$\pm h_\mu\sqrt{-1}$	$\pm h_{\mu+1}\sqrt{-1}$	....	$\pm h_\nu\sqrt{-1}$,
Multiplicity,	m_μ	$m_{\mu+1}$	....	m_ν,

in which m_0 denotes the multiplicity of the latent root $h_0 = 0$, m_1 denotes the multiplicity of each of the latent roots $\pm h_1\sqrt{-1}$, etc. Let $h_1, h_2, \ldots h_\mu$, be integer multiples of 2π, and $h_{\mu+1}, \ldots h_\nu$, any real quantities other than integer multiples of 2π. Since θ is real, its identical equation is then, if $m_0 \pm 0$,

$$F(\theta) \equiv \theta(\theta^2 + h_1^2)(\theta^2 + h_2^2)\ldots\ldots(\theta^2 + h_\nu^2) = 0.\dagger$$

Let x be any scalar, and let $f_{(r)}^{(1)} x$ and $f_r^{(2)}(x)$ be defined as follows:

$$f_r^{(1)}(x) = \left(\frac{F(x)}{x - h_r\sqrt{-1}}\right) : \left(\frac{F(x)}{x - h_r\sqrt{-1}}\right)_{x = h_r\sqrt{-1}},$$

$$f_r^{(2)}(x) = \left(\frac{F(x)}{x + h_r\sqrt{-1}}\right) : \left(\frac{F(x)}{x + h_r\sqrt{-1}}\right)_{x = -h_r\sqrt{}}$$

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* Proc. Lond. Math. Soc., Vol. XXII. p. 458.

† Ibid., p. 462.

for $r = 0, 1, 2, \ldots . \mu, \ldots . \nu$. Since $f_0^{(1)}(x) = f_0^{(2)}(x)$, either of these two functions may be denoted simply by $f_0(x)$. We then have

$$f_0(\theta) + f_1^{(1)}(\theta) + f_1^{(2)}(\theta) + \ldots . f_\nu^{(1)}(\theta) + f_\nu^{(2)}(\theta) = 1;$$

$$(f_r^{(p)}(\theta))^2 = f_r^{(p)}(\theta),$$

for $p = 1, 2$, and $r = 0, 1, 2, \ldots . \mu, \ldots . \nu$;

$$f_r^{(p)}(\theta) \cdot f_s^{(q)}(\theta) = 0,$$

for $p, q = 1, 2$, and $r, s = 0, 1, 2, \ldots . \mu, \ldots . \nu$, but $r \neq s$; and

$$\begin{aligned} \text{tr.} f_0(\theta) &= f_0(\text{tr.}\ \theta) \\ &= f_0(-\theta) \\ &= f_0(\theta), \\ \text{tr.} f_r^{(1)}(\theta) &= f_r^{(1)}(\text{tr.}\ \theta) \\ &= f_r^{(1)}(-\theta) \\ &= f_r^{(2)}(\theta), \end{aligned}$$

for $r = 1, 2, 3 \ldots . \mu, \ldots . \nu$. We also have

$$\theta = 0 \,. f_0(\theta) + h_1\sqrt{-1} f_1^{(1)}\theta - h_1\sqrt{-1} f_1^{(2)}\theta + \ldots .$$
$$+ h_\nu\sqrt{-1} f_\nu^{(1)}(\theta) - h_\nu\sqrt{-1} f_\nu^{(2)}(\theta);$$

therefore, if $f(\theta)$ denotes any polynomial in powers of θ or convergent power series in θ,

$$f(\theta) = f0 \,. f_0(\theta) + f(h_1\sqrt{-1}) f_1^{(1)}(\theta) + f(-h_1\sqrt{-1}) f_1^{(2)}(\theta)$$
$$+ \ldots . + f(h_\nu\sqrt{-1}) f_\nu^{(1)}(\theta) + f(-h_\nu\sqrt{-1}) f_\nu^{(2)}(\theta).$$

Thus

$$\phi = e^\theta = e^0 f_0(\theta) + e^{h_1\sqrt{-1}} f_1^{(1)}(\theta) + e^{-h_1\sqrt{-1}} f_1^{(2)}(\theta) + \ldots .$$
$$+ e^{h_\nu\sqrt{-1}} f_\nu^{(1)}(\theta) + e^{-h_\nu\sqrt{-1}} f_\nu^{(2)}(\theta).$$

From the relations given above between the functions with the same subscript it is evident that this matrix is orthogonal.

Let now

$$\begin{aligned}\theta_1 = \theta - \big[2\,h_1\sqrt{-1}\,(f_1^{(1)}(\theta) - f_1^{(2)}(\theta))& \\ + 2\,h_2\sqrt{-1}\,(f_2^{(1)}(\theta) - f_2^{(2)}(\theta)) &+ \ldots. \\ + 2\,h_\mu\sqrt{-1}\,(f_\mu^{(1)}(\theta) - f_\mu^{(2)}(\theta))\big]& \\ = 0\,(f_0(\theta) + f_1^{(1)}(\theta) + f_1^{(2)}(\theta) + \ldots. + f_\mu^{(1)}(\theta) + f_\mu^{(2)}(\theta))& \\ + h_{\mu+1}\sqrt{-1}f_{\mu+1}^{(1)}(\theta) - h_{\mu+1}\sqrt{-1}f_{\mu+1}^{(2)}(\theta) &+ \ldots. \\ + h_\nu\sqrt{-1}f_\nu^{(1)}(\theta) - h_\nu\sqrt{-1}f_\nu^{(2)}(\theta).&\end{aligned}$$

The matrix θ_1 is then skew symmetric, and its latent roots are 0, $\pm h_{\mu+1}\sqrt{-1}$, etc.; θ_1 is moreover real, since $f_{\mu+1}^{(1)}\theta - f_{\mu+1}^{(2)}(\theta)$, $f_{\mu+2}^{(1)}(\theta) - f_{\mu+2}^{(2)}(\theta)$, etc., are purely imaginary scalar multiples of real matrices. We also have

$$\phi = e^\theta = e^{\theta_1}.$$

If $m_0 = 0$, that is, if zero is not a latent root of θ, we may proceed in a precisely similar way to find the matrix θ_1.

3. Since no integer multiple of $2\pi\sqrt{-1}$, other than zero, is a latent root of θ_1, hence it follows that no odd multiple of $\pi\sqrt{-1}$ is a latent root of $\frac{\theta_1}{2}$; therefore, the matrix

$$\psi = e^{\frac{\theta_1}{2}}$$

has no latent root equal to -1. For the latent roots of ψ are contained in the expression e^H, for H equal successively to the distinct latent roots of θ_1.

We have

$$\psi^2 = \left(e^{\frac{\theta}{2}}\right)^2 = e^\theta = \phi.$$

Since θ_1 is real, ψ is real; and ψ is orthogonal, for we have

$$\begin{aligned}\psi\,.\,\text{tr.}\,\psi &= e^{\frac{\theta_1}{2}}\,.\,e^{\text{tr.}\frac{\theta_1}{2}} \\ &= e^{\frac{\theta_1}{2}}\,.\,e^{-\frac{\theta_1}{2}} \\ &= e^{\frac{\theta_1}{2}-\frac{\theta_1}{2}} \\ &= 1.\end{aligned}$$

Since -1 is not a latent root of ψ,

$$| \psi | = 1.$$

Or, since $e^{\frac{\theta_1}{4}}$ is orthogonal, and $\left(e^{\frac{\theta_1}{4}}\right)^2 = e^{\frac{\theta_1}{2}}$, therefore,

$$| \psi | = \left| e^{\frac{\theta_1}{2}} \right| = \left| e^{\frac{\theta_1}{4}} \right|^2 = 1.$$

Therefore, every real proper orthogonal matrix has among its square roots one or more real proper orthogonal matrices of which -1 is not a latent root.

4. Since

$$| \psi + 1 | \neq 0,$$

we may put

$$\Upsilon = \frac{1 - \psi}{1 + \psi};$$

in which case Υ will be real, and we shall have

$$\text{tr.}\,\Upsilon = \frac{1 - \text{tr.}\,\psi}{1 + \text{tr.}\,\psi} = \frac{1 - \psi^{-1}}{1 + \psi^{-1}} = \frac{\psi - 1}{\psi + 1} = -\Upsilon,$$

and also

$$\psi = \frac{1 - \Upsilon}{1 + \Upsilon}.$$

Therefore, we may put

$$\phi = \psi^2 = \left(\frac{1 - \Upsilon}{1 + \Upsilon}\right)^2,$$

for a proper choice of the skew symmetric matrix Υ.

§ 2. Real Improper Orthogonal Matrices.

5. If Φ is a real improper orthogonal matrix of which unity is a latent root of even multiplicity,* it is the negative of a real proper orthogonal matrix; therefore by (4) we may put

$$\Phi = -\left(\frac{1 - \Upsilon}{1 + \Upsilon}\right)^2,$$

for a proper choice of the real skew symmetric matrix Υ.

* This includes the case in which unity is not a latent root of Φ; the multiplicity of unity is then zero.

6. Let Φ be any real improper orthogonal matrix. Then if ω denotes a matrix whose determinant is equal to -1, and whose constituents are all zero except those in the principal diagonal which are severally equal to ± 1, the matrix

$$\phi = \omega \Phi$$

is a real proper orthogonal matrix. For

$$\begin{aligned} \breve{\phi}\phi &= \breve{\Phi}\breve{\omega} \,.\, \omega\Phi \\ &= \breve{\Phi}\omega^2\Phi \\ &= \breve{\Phi}\Phi \\ &= 1. \end{aligned}$$

Moreover,

$$|\phi| = |\omega| \,.\, |\Phi| = 1.$$

Therefore, we may put

$$\phi = \left(\frac{1 - \Upsilon}{1 + \Upsilon}\right)^2$$

for a proper choice of the real skew symmetric matrix Υ. Whence, since $\omega^2 = 1$, we derive

$$\Phi = \omega\phi = \omega\left(\frac{1 - \Upsilon}{1 + \Upsilon}\right)^2.$$

Note on Imaginary Orthogonal Matrices.

Let ϕ be an imaginary proper orthogonal matrix whose distinct latent roots are $1, -1, g, g^{-1}$; and let the rational integral function of ϕ of lowest order that vanishes be

$$(\phi - 1)^m (\phi + 1) (\phi - g)^p (\phi - g^{-1})^p.$$

Let

$$A = \frac{[(\phi-1)^m-(-1-1)^m][(\phi-1)^m-(g-1)^m]^p[(\phi-1)^m-(g^{-1}-1)^m]^p}{[-(-1-1)^m][-(g-1)^m]^p[-(g^{-1}-1)^m]^p},$$

$$B = \frac{[(\phi+1)-(1+1)]^m[(\phi+1)-(g+1)]^p[(\phi+1)-(g^{-1}+1)]^p}{[-(1+1)]^m[-g+1)]^p[-(g^{-1}+1)]^p},$$

$$C = \frac{[(\phi-g)^p-(1-g)^p]^m[(\phi-g)^p-(-1-g)^p][(\phi-g)^p-(g^{-1}-g)^p]^p}{[-(1-g)^p]^m[-(-1-g)^p][-(g^{-1}-g)^p]^p};$$

let D be obtained from C by interchanging g and g^{-1} in the expression for C. Then

$$A + B + C + D = 1;$$
$$A^2 = A, \quad B^2 = B, \quad C^2 = C, \quad D^2 = D,$$
$$AB = BA = AC = CA = \dots = 0,$$

(that is, all binary products formed from two different letters vanish);

$$\text{tr. } A = A, \quad \text{tr. } B = B, \quad \text{tr. } C = D, \quad \text{tr. } D = C.$$

Moreover,

$$\begin{array}{ll} (\phi - 1)^{m-1} A \mp 0, & (\phi - 1)^m A = 0, \\ & (\phi + 1) B = 0, \\ (\phi - g)^{p-1} C \mp 0, & (\phi - g)^p C = 0, \\ (\phi - g^{-1})^{p-1} D \mp 0, & (\phi - g^{-1})^p D = 0. \end{array}$$

I find that the matrix B is separable into a sum of two matrices, B_1 and B_2, such that

$$B_1^2 = B_1, \qquad B_2^2 = B_2,$$
$$\text{tr. } B_2 = B_1,$$
$$B_1 B_2 = B_2 B_1 = 0.*$$

* The products of B_1 and B_2 by or into either of the letters A, C, or D also vanish. Thus,

$$(B_1 + B_2) A = BA = 0;$$
$$\therefore B_1 A = B_1 (B_1 + B_2) A = 0.$$

If now

$$\psi = [1 + c_1 \overline{\phi - 1} + c_2 \overline{\phi - 1}^2 + \ldots. + c_{m-1} (\phi - 1)^{m-1}] A$$
$$+ \sqrt{-1}\, B_1 - \sqrt{-1}\, B_2 + \sqrt{g} \left[1 + c_1 \left(\frac{\phi - g}{g}\right) + c_2 \left(\frac{\phi - 1}{g}\right)^2\right.$$
$$\left. + \ldots + c_{p-1} \left(\frac{\phi - 1}{g}\right)^{p-1}\right] C + (\sqrt{g})^{-1} \left[1 + c_1 \left(\frac{\phi - g^{-1}}{g^{-1}}\right)\right.$$
$$\left. + c_2 \left(\frac{\phi - g^{-1}}{g^{-1}}\right)^2 + \ldots + c^{p-1} \left(\frac{\phi - g^{-1}}{g^{-1}}\right)^{p-1}\right] D,$$

where $1, c_1, c_2$, etc. denote the coefficients of x in the expansion by the binomial theorem of $(1 + x)^{\frac{1}{2}}$; then -1 will not be a latent root of ψ, and we shall have

$$\psi^2 = \phi,$$
$$\psi \,.\, \text{tr.}\, \psi = 1.$$

Therefore, proceeding as in (4), it may be shown that we have

$$\phi = \left(\frac{1 - \Upsilon}{1 + \Upsilon}\right)^2$$

for a proper choice of the skew symmetric matrix Υ.

This proof may be extended to any imaginary proper orthogonal matrix for which the nullity of $\phi + 1$ is equal to the multiplicity of the latent root -1.

For any matrix ϕ whose determinant does not vanish (that is, of which zero is not a latent root), a matrix ϑ can always be found such that

$$\phi = e^{\vartheta}.$$

Let ϑ be determined by Sylvester's formula as a finite polynomial in powers of ϕ; thus let

$$\vartheta = f(\phi).$$

We then have

$$\text{tr.}\, \vartheta = f(\text{tr.}\, \phi);$$

whence, if ϕ is orthogonal, it follows that

$$\vartheta \,.\, \text{tr.}\, \vartheta = \text{tr.}\, \vartheta \,.\, \vartheta.$$

Let

$$\frac{\vartheta + \text{tr.}\, \vartheta}{2} = \theta_0, \qquad \frac{\vartheta - \text{tr.}\, \vartheta}{2} = \theta;$$

from the preceding equation it follows that

$$\theta_0 \,.\, \theta = \theta \,.\, \theta_0\,;$$

therefore

$$\phi = e^{\vartheta} = e^{\theta_0 + \theta} = e^{\theta_0} e^{\theta}.$$

Since θ_0 is symmetric, e^{θ_0} is symmetric. We have

$$(e^{\theta_0})^2 = e^{2\theta_0} = e^{\vartheta + \mathrm{tr}.\vartheta} = e^{\vartheta} \,.\, e^{\mathrm{tr}.\vartheta} = \phi \,.\, \mathrm{tr}.\phi = 1\,;$$

therefore, the first factor in the above expression for ϕ is a symmetric square root of unity, that is, is a symmetric orthogonal matrix. Since θ is skew symmetric, e^{θ} is a proper orthogonal matrix. Moreover, e^{θ} can be represented by the square of Cayley's expression. For, if no integer multiple of $2\pi\sqrt{-1}$ is a latent root of θ, $e^{\frac{\theta}{2}}$ can be represented by Cayley's expression; if, on the contrary, there are integer multiples of $2\pi\sqrt{-1}$ among the latent roots of θ, a skew symmetric matrix θ_1, can always be found of which no integer multiple of $2\pi\sqrt{-1}$ is a latent root, and such that

$$e^{\theta} = e^{\theta_1}.$$

Therefore, in either case the theorem is true.

May 1, 1893.

Note on Symmetric Orthogonal Matrices.

Every symmetric orthogonal matrix is a symmetric square root of unity, and therefore, if Φ is a symmetric orthogonal matrix, an orthogonal matrix ϖ can always be found to satisfy the equation

$$\Phi = \varpi \omega \varpi^{-1},$$

in which ω is a matrix whose constituents are all zero except those in the principal diagonal which are severally equal to ± 1.

If Φ is real, ϖ may be taken real, and hence it follows from the theorems of § 1 and § 2 that, for a proper choice of the real skew symmetric matrix Υ, and of ω' a matrix similar to ω, we may put

$$\varpi = \left(\frac{1-\Upsilon}{1+\Upsilon}\right)^2 \omega'.$$

Therefore,

$$\Phi = \left(\frac{1-\Upsilon}{1+\Upsilon}\right)^2 \omega' . \omega . \omega' \left(\frac{1+\Upsilon}{1-\Upsilon}\right)^2 = \left(\frac{1-\Upsilon}{1+\Upsilon}\right)^2 \omega \left(\frac{1+\Upsilon}{1-\Upsilon}\right)^2.$$

August 17, 1893.

XIV.

CONTRIBUTION FROM THE SALISBURY LABORATORY OF THE WORCESTER POLYTECHNIC INSTITUTE.

ON THE FORMATION OF CHLOR AND BROMBENZOIC ANHYDRIDES.

BY GEORGE D. MOORE AND DANIEL F. O'REGAN.

Presented June 14, 1893.

IN a previous paper * entitled "On the Formation of the Anhydrides of Benzoic and substituted Benzoic Acids," we have shown that by the action of phosphorpentoxide upon benzoic and mono-nitrobenzoic acids in the presence of an excess of benzol at the boiling temperature the anhydrides of these *acids* are produced. Further investigation has shown that the monochlor and monobrombenzoic acids behave in a similar manner.

The process by which the chlor and bromanhydrides are prepared is essentially the same as that already described under the nitro compounds. The only difference worthy of note consists in using rather a larger quantity of phosphorpentoxide, and in boiling the mixture somewhat longer. Thus, whereas in the case of the nitro anhydrides we employed equal weights of acid and phosphorpentoxide, boiling with benzol for four hours, the halogen compounds require about one fifth excess of phosphorpentoxide and five to six hours boiling.

I. *Orthochlorbenzoic Anhydride.*

The orthochlorbenzoic acid necessary for the preparation of this substance was made according to the method described by Anschütz and one of us,† by treating salicylic acid with phosphorpentachloride, and, after rectifying the product *in vacuo*, decomposing it by distillation at ordinary atmospheric pressure.

10 grams of orthochlorbenzoic acid, prepared in this manner and melting at 137°, were heated with 12 grams of phosphorpentoxide

* These Proceedings, XXVII. 93. † Ann. Chem., CCXXXIX. 326.

and about 200 c. c. of dry benzol under a reverse condenser for about six hours. The light brown mother liquor was then decanted hot from the insoluble residue, the latter boiled up with fresh benzol, this extract added to the first, and the whole concentrated to a small volume. No precipitate appearing, the concentration was continued until a thick crust was obtained. This, after crystallization from ligroine, yielded an abundance of fine white needles, which melted at 141° and gave on analysis the following values: —

0.1452 gr. substance gave 0.1425 gr. AgCl.

0.1346 gr. gave 0.2798 gr. CO_2 and 0.0348 gr. H_2O.

	Calculated for $C_6H_4 \begin{cases} (1)\,Cl \\ (2)\,CO \end{cases} \!\!>\! O.$ $C_6H_4 \begin{cases} (2)\,CO \\ (1)\,Cl \end{cases}$	Found.
C	56.96	56.70
H	2.71	2.87
Cl	24.07	24.28

The orthochlorbenzoic anhydride is very soluble in alcohol, ether, chloroform, and benzol, less soluble in ligroine. From this last it is precipitated in the form of glittering white needles. Water and alkalies attack it slowly in the cold, more readily on heating.

II. *Metachlorbenzoic Anhydride.*

After numerous fruitless attempts to prepare metachlorbenzoic acid from benzoic acid by the method of Hübner and Weiss; * we had recourse to that of Sandmeyer,† which proved perfectly satisfactory. For the preparation of the acid on a laboratory scale this method leaves little to be desired.

10 grams of the pure acid melting at 153° were boiled up under a reverse condenser with 12 grams of phosphorpentoxide and an excess of benzol for six hours. The decanted mother liquor, together with benzol washings from the phosphoric residue, were concentrated, and the white crystalline mass which separated out, purified by pressing between filters and recrystallizing from fresh benzol. The substance thus obtained did not show a constant melting point. It was therefore washed several times with dilute potash, dried, and again crystallized. It now melted constant at 89°, and gave on analysis the following: —

* Ber. d. ch. G., VI. 175.

† Ber. d. ch. G., XVII. 1634.

0.1900 gr. substance gave 0.1833 gr. AgCl.
0.1944 gr. gave 0.4052 gr. CO_2 and 0.0497 gr. H_2O.

	Calculated for $C_6H_4\left\{\begin{matrix}(1)\,Cl\\(3)\,CO\end{matrix}\right. \rangle O. \; C_6H_4\left\{\begin{matrix}(3)\,CO\\(1)\,Cl\end{matrix}\right.$	Found.
C	56.96	56.84
H	2.71	2.84
Cl	24.07	23.85

Metachlorbenzoic anhydride is readily soluble in alcohol, ether, benzol, and chloroform, less easily in ligroine. It crystallizes best from benzol, in the form of yellowish white needles.

III. *Parachlorbenzoic Anhydride.**

This substance was prepared from parachlorbenzoic acid, m.pt. 236°, phosphoric anhydride, and benzol, in the same manner as the ortho and meta anhydrides. Like these it is easily soluble in alcohol, ether, benzol, and chloroform, less soluble in petroleum ether. It crystallizes readily from warm benzol in glittering leaflets, which melt at 186°. The analyses gave: —

0.1718 gr. substance gave 0.1648 gr. AgCl.
0.2011 gr. gave 0.4185 gr. CO_2 and 0.0590 gr. H_2O.

	Calculated for $C_6H_4\left\{\begin{matrix}(1)\,Cl\\(4)\,CO\end{matrix}\right. \rangle O. \; C_6H_4\left\{\begin{matrix}(4)\,CO\\(1)\,Cl\end{matrix}\right.$	Found.
C	56.96	56.75
H	2.71	3.26
Cl	24.07	23.71

Anhydrides of the Monobrombenzoic Acids.

The anhydrides of ortho, meta, and parabrombenzoic acids were prepared from the acids in a similar manner. The orthobrombenzoic

* The parachlorbenzoic acid used in this experiment, as well as the parabrombenzoic acid, to be mentioned later, were kindly furnished us by Prof. C. L. Jackson of the Harvard College Laboratory, to whom we would here express our warmest thanks for both preparations.

acid employed was obtained from anthranilic acid by means of the Sandmeyer * reaction, which, as in the case of the metachlor acid above mentioned, we found admirably adapted to our purpose.

I. *Orthobrombenzoic Anhydride.*

Crystallizes from ligroine in fine, white, prismatic needles melting at 141°. Readily soluble in ether and chloroform, less easily in benzol, alcohol, and ligroine. The analyses gave : —

0.1663 gr. substance gave 0.1615 gr. AgBr.
0.1832 gr. gave 0.2928 gr. CO_2 and 0.0390 gr. H_2O.

	Calculated for $C_6H_4 \begin{cases} (1)\,Br \\ (2)\,CO \end{cases} \!\!\!>O. \; C_6H_4 \begin{cases} (2)\,CO \\ (1)\,Br \end{cases}$	Found.
C	43.75	43.58
H	2.09	2.36
Br	41.67	41.32

II. *Metabrombenzoic Anhydride.*

Crystallizes from benzol in glittering white leaflets melting at 97° Readily soluble in ether and chloroform, less easily in alcohol, benzol, and ligroine. The analyses gave : —

	Calculated for $C_6H_4 \begin{cases} (1)\,Br \\ (3)\,CO \end{cases} \!\!\!>O. \; C_6H_4 \begin{cases} (3)\,CO \\ (1)\,Br \end{cases}$	Found.
C	43.75	43.50
H	2.09	2.10
Br	41.67	41.55

III. *Parabrombenzoic Anhydride.*

Crystallizes from benzol in thick prisms, from chloroform in small tablets. Is decidedly more insoluble in the common organic solvents than either the ortho or the meta isomer. Melting point 212 to 213°. This body has already been described by Jackson and Rolfe ; † we have therefore considered an analysis unnecessary.

* Ber. d. ch. G., XVIII. 1495. † These Proceedings, XXII. 256.

XV.

CONTRIBUTION FROM THE SALISBURY LABORATORY OF THE WORCESTER POLYTECHNIC INSTITUTE.

ON THE FORMATION OF SUBSTITUTED BENZOPHENONES.

By George D. Moore and Daniel F. O'Regan.

The preparation of benzophenone by heating benzoic acid, benzol, and phosphorpentoxide in sealed tubes at 180–200° has already been described by Kollarits and Merz.* The same authors † have also shown that benzoic anhydride reacts, under similar conditions, in the same manner as benzoic acid. We have proved ‡ that not only benzoic acid, but also the three isomeric mono-nitro, chlor, and brom acids yield anhydrides as the first product of this reaction. In the present paper we will describe the preparation of the nitro, chlor, and brom benzophenones from these anhydrides.

I. *Action of Phosphorpentoxide upon Orthonitrobenzoic Anhydride in an Excess of Benzol.*

10 grams of orthonitrobenzoic anhydride, m.pt. 133°, prepared by boiling a benzol solution of the acid with phosphorpentoxide, were heated in a sealed tube with 15 grams phosphoric anhydride and 25–30 c.c. pure dry benzol at 150° for about four hours. A slight reaction takes place in the cold, as evidenced by the rapid blackening of the solid constituents of the mixture, although the benzol remains uncolored.

After heating, the dark-colored mother liquor was decanted from the black residue, decolorized by means of bone-black, and concentrated until, on cooling, crystals were deposited. These, after washing with pure benzol and drying between filters, showed a melting point of 132–133°. The body is therefore the unaltered anhydride.

The black residue was a hard, vitreous mass, which clung so tenaciously to the tube that it was necessary to crush the latter completely

* Zeitschr. für Chemie, 1871, p. 705. Ber. d. ch. G., V. 447. † *Loc. cit.*
‡ These Proceedings, XXVII. 93.

in order to separate them. The fragments were then pulverized in a mortar, extracted with dilute potash, washed clean, and boiled up with 150–200 c.c. of absolute alcohol under a reverse cooler. This alcoholic liquor gave, after treatment with bone-black and concentrating, a crystalline precipitate, which we purified with considerable difficulty as the quantity was exceedingly small. We finally succeeded in getting a sufficient amount of it of constant melting point (104–105°) for an analysis.

0.1010 gr. substance gave 0.2537 gr. CO_2 and 0.0392 gr. H_2O.

	Calculated for $C_6H_4\begin{cases}(1)\ NO_2\\(2)\ COC_6H_5\end{cases}$	Found.
C	68.72	68.50
H	3.97	4.31

The yield is so small that we could not obtain a sufficient quantity to enable us to examine its properties as fully as we could wish. All attempts to increase the yield by varying the proportions, temperature, time of heating, etc., were without effect. Benzol takes up little or nothing from the raw product, and the same may be said of the other common solvents with the exception of boiling absolute alcohol. Dilute alkalies extract more or less orthonitrobenzoic acid. The concentrated alcoholic solution remains clear for several days, then manifests a slight turbidity, and finally deposits microscopic crystals. In several instances we have succeeded in obtaining only a thick syrup which could not be made to crystallize.

From the analysis of the substance and the method of its preparation we conclude that it is the orthonitrobenzophenone described by Geigy and Königs,* and interpret its formation by the following reactions: —

$$\begin{matrix} C_6H_4\begin{cases}(1)\ NO_2\\(2)\ CO\end{cases} \\ \quad\quad\quad\searrow \\ \quad\quad\quad\quad O \\ \quad\quad\quad\nearrow \\ C_6H_4\begin{cases}(2)\ CO\\(1)\ NO_2\end{cases}\end{matrix} + C_6H_6 = C_6H_4\begin{cases}(1)\ NO_2\\(2)\ COC_6H_5\end{cases} + C_6H_4\begin{cases}(1)\ NO_2\\(2)\ COOH\end{cases}$$

$$\begin{matrix} C_6H_4\begin{cases}(1)\ NO_2\\(2)\ CO\end{cases} \\ \quad\quad\quad\searrow \\ \quad\quad\quad\quad O \\ \quad\quad\quad\nearrow \\ C_6H_4\begin{cases}(2)\ CO\\(1)\ NO_2\end{cases}\end{matrix} + 2\,C_6H_6 = 2\,C_6H_4\begin{cases}(1)\ NO_2\\(2)\ COC_6H_5\end{cases} + H_2O$$

* Ber. d. ch. G., XVIII. 2403.

The first of these reactions may account for the free acid which is obtained, as above mentioned, by the action of dilute alkalies on the raw product. Unchanged anhydride would, however, give the same result, and it is quite possible that appreciable quantities thereof may easily have been retained in the black residue after its treatment with benzol, owing to its gummy vitreous nature.

II. *Action of Phosphorpentoxide upon Metanitrobenzoic Anhydride in an Excess of Benzol.*

6 grams of metanitrobenzoic anhydride, m.pt. 161°, prepared by boiling a benzol solution of the acid with phosphorpentoxide, were heated in a sealed tube with 5 grams phosphoric anhydride, and 25–30 c.c. pure dry benzol for about four hours at 190–200°. After the reaction was completed, the contents of the tube consisted of a hard black vitreous residue, and a brownish supernatant liquid. This last was poured off, the residue washed several times with clean benzol, and the washings added to the decanted portion. The liquid was then purified by means of bone-black, and, after concentration, threw down a precipitate of fine white needles which, by their melting point, 161°, and ready solubility in alkalies, were easily identified as metanitrobenzoic anhydride.

The black vitreous residue from the benzol mother liquor was pulverized, freed from benzol as completely as possible by pressing between filters, and then extracted, first with potash to remove possible traces of acid and anhydride, then by repeated boiling with absolute alcohol. The dark red alcoholic extract gave, after treatment with bone-black and concentrating, a deposit of dark brown prismatic crystals, melting at 89°. By repeated crystallization from absolute alcohol these were finally obtained pure in the form of grayish white scales or leaflets, melting at 94–95°. The analyses gave the following values: —

0.2086 gr. substance gave 0.5248 gr. CO_2 and 0.0809 gr. H_2O.

0.2044 gr. substance gave 10.4 c.c. nitrogen gas at 10°.4 and 757.3 mm.

	Calculated for $C_6H_4\left\{\begin{matrix}(1)\ NO_2\\(3)\ COC_6H_5.\end{matrix}\right.$	Found.
C	68.72	68.60
H	3.97	4.30
N	6.17	6.06

The substance is obviously metanitrobenzophenone, and its formation may be ascribed to reactions analogous to those above given for the corresponding ortho compound. The yield is much better than in the case of the ortho body, and its purification is a comparatively simple operation. It is insoluble in water, easily soluble in hot alcohol, benzol, and chloroform. Ether also dissolves it readily. Absolute alcohol is the best medium for its crystallization.

III. *Action of Phosphorpentoxide upon Paranitrobenzoic Anhydride in an Excess of Benzol.*

4.5 grams paranitrobenzoic anhydride, m.pt. 184°, prepared from the acid and phosphoric anhydride, were heated in a sealed tube with 5 grams phosphorpentoxide and 30–35 c.c. pure dry benzol at 190–200° for about four hours. As with the ortho and meta anhydrides, the product of the reaction consisted of two portions, a solid black deposit, and a more or less dark-colored supernatant liquid. The latter gave, after purification and concentration, a precipitate of anhydride, easily identified by its crystal form and melting point.

The residue was worked up in the same manner as described under the ortho and meta compounds. The chief product consisted of yellowish white scales melting at 137–138°, and, as the analyses prove, is paranitrobenzophenone.

0.2408 gr. gave 0.6081 gr. CO_2 and 0.0902 gr. H_2O.

0.1944 gr. gave 10.2 c.c. nitrogen at 16°.4 and 749.3 mm.

	Calculated for $C_6H_4{<}^{NO_2}_{CO.C_6H_5}$	Found.
C	68.72	68.87
H	3.97	4.16
N	6.17	6.02

Paranitrobenzophenone crystallizes from hot absolute alcohol in yellowish scales. It is readily soluble in ether, chloroform, ligroine, benzol, and carbon disulphide, insoluble in water.

The course of the reaction by which the substance is formed is obviously the same as in the case of the isomeric ortho and meta nitrobenzophenones. The yield is much the best of the three, the raw product is less gummy, and the quantity of anhydride recovered from the benzol mother-liquor very small. Traces of free acid are more or less present [illegible] formation of the paranitro compound by the help of the reaction above given cannot be entirely excluded.

Chlor and Brombenzophenones.

After we had succeeded in effecting the synthesis of the nitrophenones from the anhydrides, as above described, we concluded to extend the research to the corresponding halogen bodies. We found that, with the exception of the orthobrom derivative, the reaction takes place in precisely the same manner.

Orthobrombenzoic anhydride, prepared as stated in the previous paper, was heated in a sealed tube with an equivalent amount of phosphorpentoxide, and a considerable excess of benzol for four to five hours at 190 to 200°. The product was worked up as described under the nitrophenone, but without result. We were unable to obtain even a trace of brombenzoic acid, the only tangible product being a very small quantity of a yellowish oil, which could not be brought to crystallization. The operation we have repeated with varying quantities of the different factors, and varying times of heating, but without success. It will be remembered, in this connection, that in the case of the orthonitrophenone the course of the reaction left much to be desired, though we finally succeeded in obtaining enough product for analysis.

Metabrombenzophenone.

This body was prepared from metabrombenzoic anhydride, m.pt. 97°, by heating it in a sealed tube with phosphorpentoxide and benzol, and working up the product as described under the nitro compound. It crystallizes from alcohol in colorless needles, which melt at 74°, and dissolve readily in ether, chloroform, and benzol, less easily in alcohol and ligroine. The analyses gave as follows : —

0.2009 gr. substance gave 0.4401 gr. CO_2 and 0.0661 gr. H_2O.
0.1939 gr. gave 0.1390 gr. AgBr.

	Calculated for $C_6H_4\left\{\begin{matrix}(1)\ Br\\(3)\ COC_6H_5\end{matrix}\right.$	Found.
C	59.77	59.75
H	3.45	3.66
Br	30.66	30.51

Parabrombenzophenone.

From parabrombenzoic anhydride, m.pt. 212–213°, by heating to 190–200° with phosphorpentoxide and benzol. Crystallizes from

alcohol in glittering leaflets, melting at 77°. Readily soluble in alcohol, ether, benzol, chloroform, and ligroine. Analyses: —

0.2570 gr. substance gave 0.5619 gr. CO_2 and 0.0962 gr. H_2O.
0.1591 gr. gave 0.1133 gr. AgBr.

	Calculated for $C_6H_4 \begin{cases} (1)\ Br \\ (4)\ COC_6H_5. \end{cases}$	Found.
C	59.77	59.62
H	3.45	4.16
Br	30.66	30.31

Orthochlorbenzophenone.

From orthochlorbenzoic anhydride, phosphorpentoxide, and benzol. Crystallizes from ligroine in large rhombic prisms which deliquesce slowly in the air, and melt at 40–41°. Readily soluble in alcohol, ether, chloroform, and benzol, less easily in ligroine. It is best purified by distillation over a free flame and subsequent recrystallization from ligroine. Analyses: —

0.1401 gr. gave 0.3695 gr. CO_2 and 0.0531 gr. H_2O.
0.1143 gr. gave 0.0750 gr. AgCl.

	Calculated for $C_6H_4 \begin{cases} (1)\ Cl \\ (2)\ COC_6H_5. \end{cases}$	Found.
C	72.04	71.93
H	4.16	4.21
Cl	16.40	16.23

Metachlorbenzophenone.

Crystallizes from alcohol or benzol in fine needles, which melt at 83°. Easily soluble in alcohol, ether, chloroform, benzol, and ligroine. Analyses: —

0.2158 gr. substance gave 0.5681 gr. CO_2 and 0.0831 gr. H_2O.
0.2204 gr. gave 0.1450 gr. AgCl.

	Calculated for $C_6H_4 \begin{cases} (1)\ Cl \\ (3)\ COC_6H_5. \end{cases}$	Found.
C	72.04	71.80
H	4.16	4.28
Cl	16.40	16.27

Parachlorbenzophenone.

From alcohol in leaflets melting at 78°. Readily soluble in alcohol, ether, benzol, chloroform, and ligroine. Analyses: —

0.2429 gr. substance gave 0.6439 gr. CO_2 and 0.0942 gr. H_2O.
0.1954 gr. gave 0.1280 gr. AgCl.

	Calculated for $C_6H_4\left\{\begin{array}{l}(1)\ Cl \\ (4)\ COC_6H_5.\end{array}\right.$	Found.
C	72.04	72.30
H	4.16	4.31
Cl	16.40	16.19

The results of our investigations show that the formation of acid anhydrides invariably precedes that of the phenones. In the case of the substituted derivatives two classes of reactions are possible; viz. the combination of substituted anhydrides with hydrocarbons:

$$\begin{array}{l} C_6H_4\left\{\begin{array}{l}X \\ CO\end{array}\right. \\ \qquad\qquad \rangle O + 2\,C_6H_6 = 2\,C_6H_4\left\{\begin{array}{l}X \\ COC_6H_5\end{array}\right. + N_2O, \\ C_6H_4\left\{\begin{array}{l}CO \\ X\end{array}\right. \end{array}$$

or benzoic anhydride with the substituted hydrocarbon:

$$\begin{array}{l} C_6H_5CO \\ \qquad\qquad \rangle O + 2\,C_6H_5X = 2\,C_6H_4\left\{\begin{array}{l}X \\ COC_6H_5\end{array}\right. + H_2O. \\ C_6H_5CO \end{array}$$

In the first instance the nature and position of the substituting radical appear to exercise a decided influence upon the course of the reaction. The orthobrom and orthonitro anhydrides react with difficulty, possibly owing to the formation of condensation or decomposition products between the adjacent side chains. Orthochlor anhydride reacts somewhat more readily. All the meta anhydrides give good yields of phenones; the para compounds, however, work best of all.

The essential conditions of the process appear to be, first, the presence of a negative radical in the acid anhydride; second, the farther this radical is removed from the carbonyl group the more complete will be the reaction.

By allowing phosphorpentoxide to react upon chlorbenzol and benzoic acid, or brombenzol and benzoic acid, Kollarits and Merz * have obtained a chlorbenzophenone (needles from ether-alcohol, m.pt. 75.5–76°), and a brombenzophenone (radiating forms, m.pt. 81°.5), probably identical with our parachlor and parabrom compounds above described. This would indicate that the carbonyl group of the acid anhydride assumes the para position with respect to the substituting negative radical of the hydrocarbon.

We have endeavored to carry out the same reaction, using nitrobenzol and metadinitrobenzol as substituting factors, but without result, notwithstanding our efforts to improve the course of the reaction by changing the amounts of materials employed and by heating at various temperatures.

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* Ber. d. ch. G., VI. 547.

XVI.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XLI. — ON THE EXCURSION OF THE DIAPHRAGM OF A TELEPHONE RECEIVER.

By Charles R. Cross and Henry M. Phillips.

Presented January 11, 1893.

The present investigation is a continuation of one upon the same subject by Messrs. Cross and Mansfield, the results of which have already been published in these Proceedings.*

In the study of the excursion of the telephone diaphragm described in the paper referred to, the current employed was an alternating current from a dynamo-electric machine, the magnitude of which current was considerably above that of the telephone currents employed in practice. In the present investigation we have employed the currents furnished by a powerful long-distance microphone transmitter to actuate the receiver, and have measured the amplitude of the vibration of the diaphragm of the receiver under such currents when the strength of the polarizing magnet was varied.

The apparatus employed was substantially indentical with that described in the paper referred to. A more sensitive electro-dynamometer with a unifilar suspension was used, and the support holding the disk of the receiving telephone was made somewhat more rigid, as it was found that it yielded slightly under the strong pull of the polarizing magnet when this was strongly magnetized, and in close proximity to the diaphragm. The microphone, actuated by a C_3 stopped organ-pipe of large scale, blown by a carefully regulated blast, was placed in the primary circuit of an induction coil, such as is ordinarily employed with the long-distance transmitter. In the secondary circuit was placed the receiving telephone, which was to be studied, and also the electro-dynamometer and an adjustible water resistance. In a few experiments the ordinary hand magneto-receiver was used, but in most

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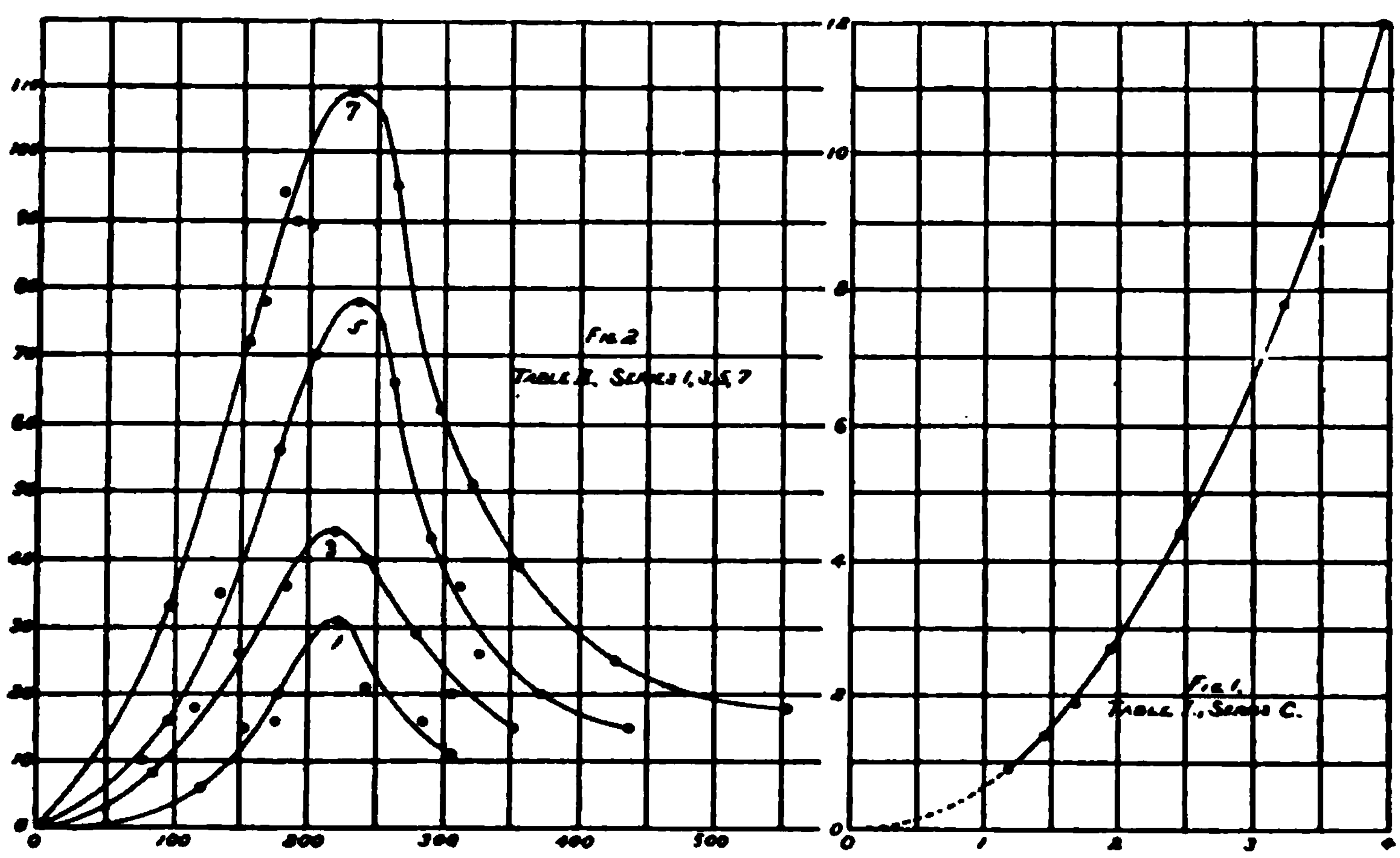
* *Ante*, page 93.

cases we employed an experimental receiver like that used in the earlier studies referred to. The core was a bar of Norway iron, ⅜ inch in diameter and 8 inches long, wound with 2,750 turns of No. 18 (B. & S.) insulated copper wire. The current which traversed these coils was furnished by a dynamo machine. It passed through an incandescent lamp and a variable resistance frame, with which last the magnet was placed in derived circuit. By varying this current any desired strength of field could be obtained. In all our experiments the core of the electro-magnet was far removed from saturation, so that we may assume the strength of its field to have been proportional to the current traversing its coils. The strength of this current was measured



in the earlier experiments by a Thomson graded galvanometer, and in the later ones by a Weston milliamperemeter. The transmitter current was furnished by a single storage cell, and the organ-pipe which served as a source of sound was placed in a distant room. The arrangement of the stroboscopic fork was similar to that used in the previous work.

The first measurements were made with an ordinary magneto-telephone as a receiver. The line current was varied, and the corresponding excursion of the diaphragm determined, with the results given in Table I. Series C is graphically illustrated in Figure 1. The values given in the table are the mean of three or more closely concordant readings. In this and the following tables the current is given in milliamperes. the excursion in terms of one micrometer division as a unit. In the figures the abscissas represent currents, and the ordinates excursions.

TABLE I.

Series A.		Series B.		Series C.	
Line Current.	Excursion.	Line Current.	Excursion.	Line Current.	Excursion.
3.94	11.9	3.97	12.3	3.96	12.0
3.06	7.1	3.35	8.5	3.22	7.8
2.52	4.7	3.12	7.4	2.47	4.4
1.96	2.7	2.68	5.3	1.94	2.7
1.49	2.5	2.16	3.4	1.68	1.9
1.21	0.9	1.83	2.4	1.45	1.4
1.06	0.7	1.49	1.5	1.19	0.9
		1.30	1.1		

It appears from these results that with the magneto-receiver now used the change in the amplitude of the vibration is approximately proportional to the change in strength of the current for the stronger currents used in the measurements, but with the weaker currents the amplitude increases at a more rapid rate. These currents as a whole, however, are higher than those reached in practice.

In subsequent experiments we used as a receiver the electro-magnetic telephone previously mentioned. The end of its core was set at a distance of $\frac{1}{32}$ inch from the diaphragm. With the undulatory current in the line coil maintained at a constant value in each separate series of experiments, while the magnetizing current was varied, results were obtained as shown in Table II. Line currents with values successively varied in the different series were produced by the microphone transmitter. The values of the magnetizing currents in milliamperes are given in the first column, the corresponding excursions of the diaphragm in terms of one division of the micrometer in the second. Series I., III., V., and VII. are represented by the curves in Figure 2.

The results reached agree very well with those obtained by Cross and Mansfield, when currents from an alternating dynamo were used, except that in these last the maximum value of the excursion was reached with a magnetizing current of 320 milliamperes, while with those obtained in the present investigation the maximum value was

reached when the magnetizing current was only 225 milliamperes. This difference arises from the fact that in the earlier experiments the end of the core of the magnet was set at a distance of $\frac{3}{64}$ inch from the diaphragm, while in the present ones it was at a distance of only $\frac{1}{32}$ inch, and so approached saturation sooner.

TABLE II.

SERIES I.

Line Current = 1.25 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
120	6	176	16
178	20	248	21
158	15	285	16
223	31	307	11

SERIES II.

Line Current = 1.5 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
117	14	244	35
150	22	280	28
184	29	301	20
220	36	350	10

SERIES III.

Line Current = 1.9 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
83	8	244	40
115	18	280	29
149	26	306	20
184	36	352	15
220	44		

SERIES IV.

Line Current = 2.2 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
83	9	245	53
119	16	283	37
151	35	308	27
181	45	351	18
223	51	486	10

SERIES V.

Line Current = 2.6 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
75	10	263	66
95	16	291	43
135	35	312	36
178	56	327	26
204	70	372	20
237	78	438	15

SERIES VI.

Line Current = 2.8 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
74	11	287	51
119	81	301	42
160	44	355	25
181	56	327	33
219	75	481	13
249	68		

SERIES VII.

Line Current = 3.87 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
96	33	265	95
190	90	297	62
155	72	322	51
167	78	356	39
181	94	428	25
201	89	554	18
232	109		

Experiments were also made with the same apparatus in which the strength of the field magnet of the telephone was kept constant by maintaining a constant current in its coils, while the line current was varied. In the first series of these the diaphragm was separated from the end of the core by a distance of $\frac{1}{32}$ inch. The results are given in Table III., and Series VIII., IX., XI., XIII., and XIV. are graphically illustrated by the curves of Figure 3.

TABLE III.

SERIES VIII.

Magnetizing Currrent = 135 milliamperes.

Line Current.	Excursion.
3.15	83
2.76	27
2.05	14

SERIES IX.

Magnetizing Current = 160 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.46	73	2.29	32
2.98	56	1.72	23
2.74	46		

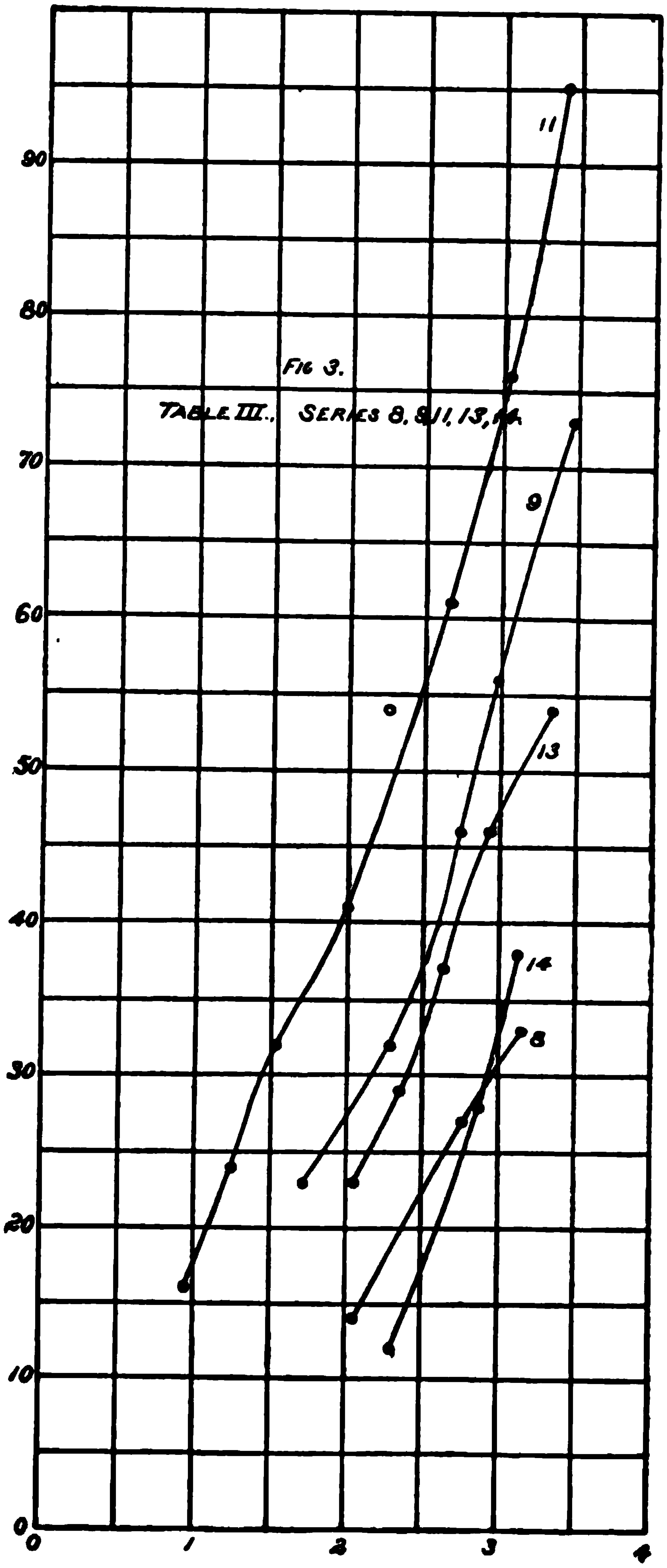


Fig 3.
Table III., Series 8, 9, 11, 13, 14.
11
9
13
14
8
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4

Series X.

Magnetizing Current = 190 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.49	95	1.91	41
3.00	82	1.45	31
2.82	69	1.25	23
2.24	49	1.12	20

Series XI.

Magnetizing Current = 256 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
4.04	113	2.00	41
3 40	95	1.53	32
3.04	76	1.25	24
2.66	61	0.94	16
2.26	54		

Series XII.

Magnetizing Current = 259 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.77	98	2.29	47
3.23	83	1.87	34
2.78	71	1.53	23
2.51	56	1.19	16

Series XIII.

Magnetizing Current = 275 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.33	54	2.35	29
2.93	46	2.05	23
2.63	37		

Series XIV.

Magnetizing Current = 310 milliamperes.

Line Current.	Excursion.
3.12	38
2.87	28
2.30	12

These figures show that the change in the amplitude of the vibration of the diaphragm is approximately proportional to the change in strength of the line current within the limits of line current and magnetizing current used, and with the distance $\frac{1}{32}$ inch between the core and diaphragm. Some irregularities in the figures are due to a small variation in the strength of the magnetizing current, which was furnished by a dynamo machine whose speed fluctuated a little.

A series of observations was next made in which the magnetizing current was varied as with the previous Series I. to VII., and the line current kept constant, but with the diaphragm at a distance of $\frac{1}{64}$ inch from the pole of the field-magnet. The results are given in Table IV., and those of all the series except XVII. are shown graphically in Figure 4.

TABLE IV.

SERIES XV.

Line Current = 0.82 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
161	13	214	18
173	16	230	14
183	19	235	14
189	22	236	22

SERIES XVI.

Line Current = 1.25 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
97	11	182	18
117	16	191	18
135	20	207	25
150	23	209	29
169	17	217	31

SERIES XVII.

Line Current = 1.45 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
202	38	229	40
216	35	240	53

SERIES XVIII.

Line Current = 1.70 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
97	18	183	31
117	27	196	30
136	32	203	40
167	31	201	37

SERIES XIX.

Line Current = 2.05 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
108	13	183	39
126	28	192	38
144	46	195	45
161	50	196	49

Series X.

Magnetizing Current = 190 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.49	95	1.91	41
3.00	82	1.45	31
2.82	69	1.25	23
2.24	49	1.12	20

Series XI.

Magnetizing Current = 256 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
4.04	113	2.00	41
3 40	95	1.53	32
3.04	76	1.25	24
2.66	61	0.94	16
2.26	54		

Series XII.

Magnetizing Current = 259 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.77	98	2.29	47
3.23	83	1.87	34
2.78	71	1.53	23
2.51	56	1.19	16

Series XIII.

Magnetizing Current = 275 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.33	54	2.35	29
2.93	46	2.05	23
2.63	37		

Series XIV.

Magnetizing Current = 310 milliamperes.

Line Current.	Excursion.
3.12	38
2.87	28
2.30	12

These figures show that the change in the amplitude of the vibration of the diaphragm is approximately proportional to the change in strength of the line current within the limits of line current and magnetizing current used, and with the distance $\frac{1}{32}$ inch between the core and diaphragm. Some irregularities in the figures are due to a small variation in the strength of the magnetizing current, which was furnished by a dynamo machine whose speed fluctuated a little.

A series of observations was next made in which the magnetizing current was varied as with the previous Series I. to VII., and the line current kept constant, but with the diaphragm at a distance of $\frac{1}{64}$ inch from the pole of the field-magnet. The results are given in Table IV., and those of all the series except XVII. are shown graphically in Figure 4.

TABLE IV.

SERIES XV.

Line Current = 0.82 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
161	18	214	18
173	16	230	14
183	19	235	14
189	22	236	22

SERIES XVI.

Line Current = 1.25 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
97	11	182	18
117	16	191	18
135	20	207	25
150	23	209	29
169	17	217	31

SERIES XVII.

Line Current = 1.45 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
202	38	229	40
216	35	240	53

SERIES XVIII.

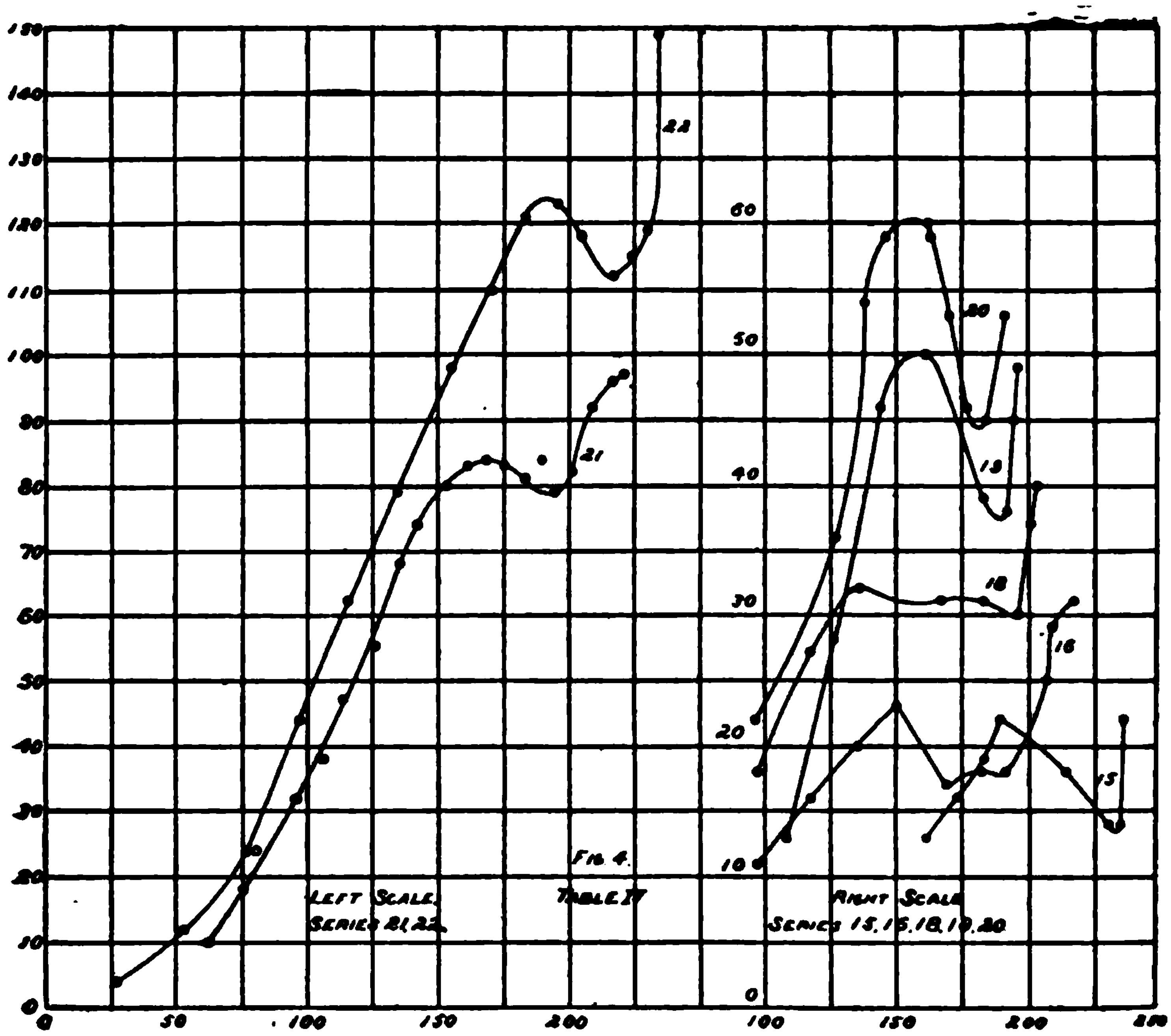
Line Current = 1.70 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
97	18	188	31
117	27	196	30
136	32	203	40
167	31	201	37

SERIES XIX.

Line Current = 2.05 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
108	13	183	39
126	28	192	38
144	46	195	45
161	50	196	49



SERIES XX.

Line Current = 2 18 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
96	22	163	59
127	36	170	53
138	54	177	46
146	59	184	45
162	60	191	53

SERIES XXI.

Line Current = 2.35 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
62	10	161	83
75	18	168	84
80	24	175	83
96	32	183	81
106	38	190	84
113	47	195	79
126	55	201	82
135	68	209	92
142	74	217	96
153	80	221	97

SERIES XXII.

Line Current = 3.55 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
27	4	183	121
58	12	196	123
76	24	205	118
97	44	217	112
115	62	224	115
134	79	230	119
155	98	234	149
170	110		

It will be noticed from the data given in the tables and the curves that with the core of the magnet at a distance of $\frac{1}{64}$ inch from the diaphragm, a first maximum of the excursion is reached with a magnetizing current not far removed from 160 milliamperes, while with a distance of $\frac{1}{32}$ inch the maximum excursion occurred when the magnetizing current had a value of about 225 milliamperes.

With the diaphragm thus close to the magnet, it was observed, as will be seen from the figures, that, after the amplitude of the vibration of the diaphragm had begun to decrease owing to the approach of the diaphragm toward saturation, there was a later increase of this amplitude, which rose even to an amount greater than for any previous value of the magnetizing current. This was brought about by the motion of the diaphragm towards the pole, the diaphragm assuming a new position of equilibrium under the increased pull of the magnet. The effect of increased proximity of the diaphragm to the core more than makes up for the opposing effect of a closer approach of the diaphragm toward saturation.

A separate study of the variation in the excursion after the second rapid rise began was made by using the strongest possible magnetizing current below that which pulled the diaphragm into contact with the core, viz. 204 milliamperes, and varying the line current, the excursions being measured as before. The results are given in Table V., and shown graphically in Figure 5.

TABLE V.

SERIES XXII *a*.

Magnetizing Current = 204 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.15	137	2.10	66
2.86	122	1.74	48
2.63	98	1.34	30
2.37	83		

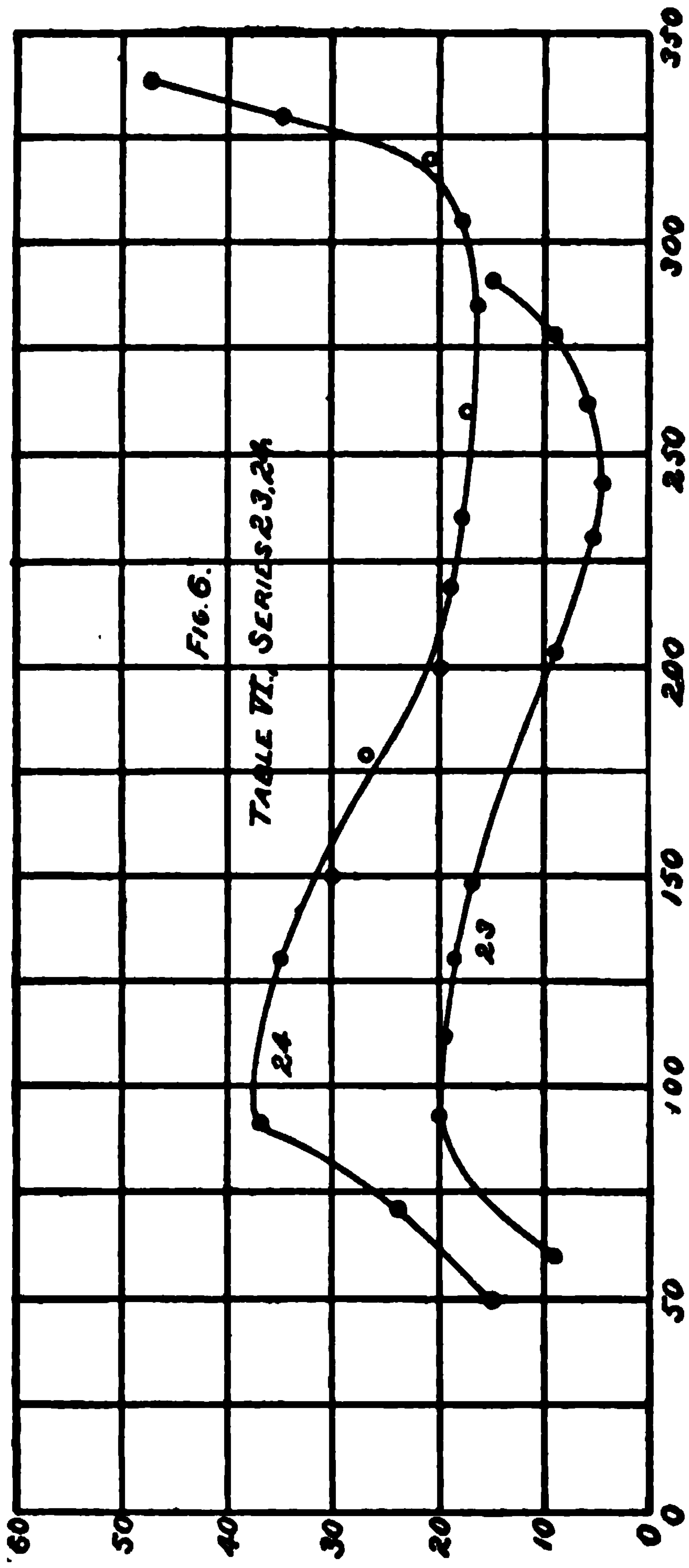


Fig. 6.
Table VI., Series 23, 24.
23
24
0
50
100
150
200
250
300
350
0
10
20
30
40
50
60

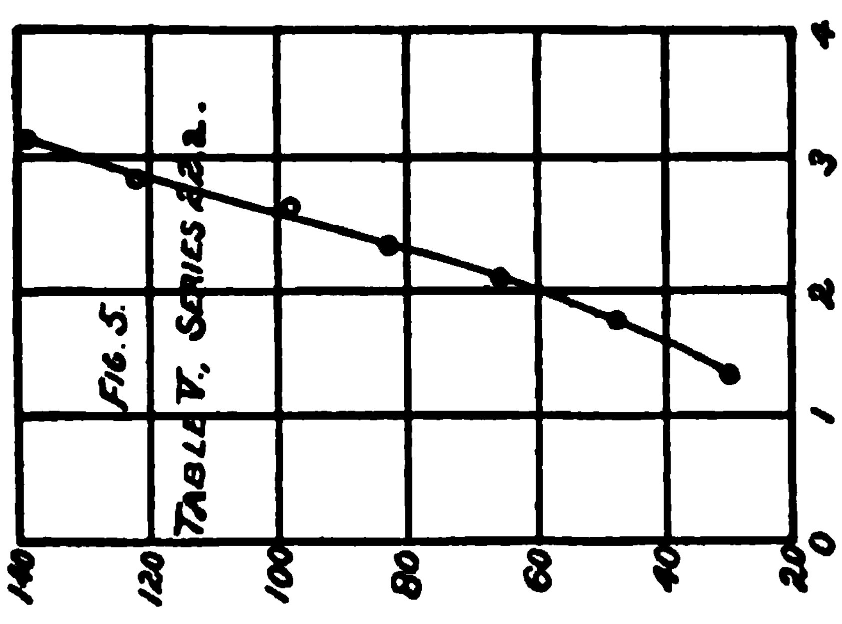


Fig. 5.
Table V., Series 22.
0
1
2
3
4
20
40
60
80
100
120
140

Table VI. and Figure 6 show the result of a similar series of measurements with the diaphragm at a distance of $\frac{3}{256}$ inch from the core. Here the first maximum of the excursion is attained with a magnetizing current of about 100 milliamperes.

TABLE VI.

SERIES XXIII.

Line Current = 1.40 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
291	15	148	17
278	9	130	18.5
262	6	112	19.5
248	4.5	93	20
230	5.5	60	9
208	9		

SERIES XXIV.

Line Current = 1.65 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
338	47.5	200	20
330	35	179	27
320	21	150	30
305	18	130	35
285	16.5	91	37
260	17.5	71	24
235	18	50	15
218	19		

With the diaphragm at a distance of $\frac{1}{128}$ inch from the core, the values for the excursion given in Table VII. were obtained. These are shown graphically in Figure 7. Here the final rise of the curve has begun even with the lowest magnetizing force employed.

TABLE VII.

SERIES XXV.

Line Current = 1.26 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
61	26	39	10
51	18	28	7

SERIES XXVI.

Line Current = 2.25 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
61	69	39	22
51	48	28	12

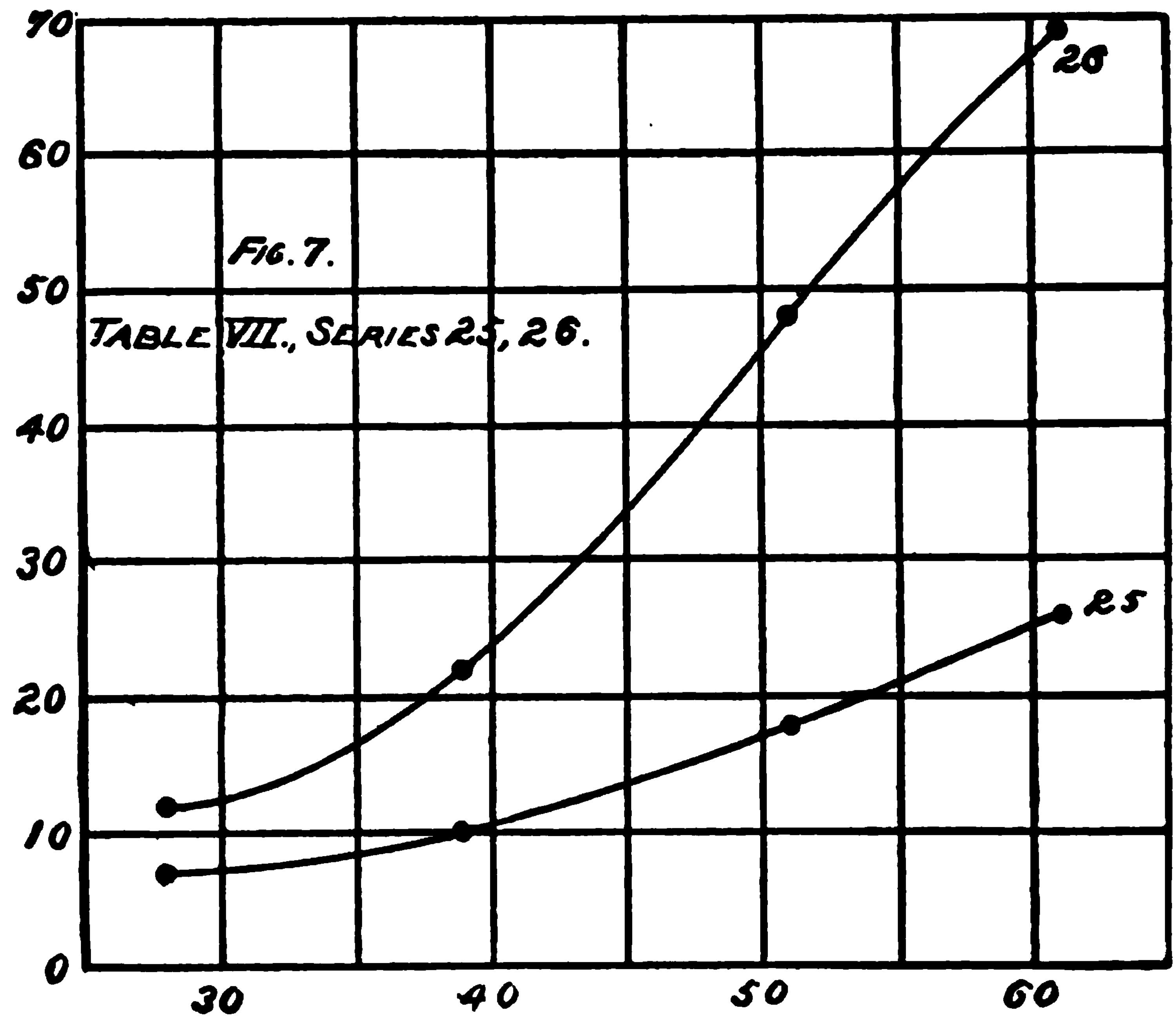


Table VIII. shows the manner in which the mean position of the diaphragm varies when the magnetizing current is increased. There is no current flowing through the line coil. The distance of the diaphragm from the core with no magnetizing current flowing was $\frac{1}{128}$ inch.

TABLE VIII.

SERIES XXVII.

Magnetizing Current.	Deflection.	Magnetizing Current.	Deflection.
0	0	50	286
14	12	61	546
28	48	72	1020
39	145		

ROGERS LABORATORY OF PHYSICS,
June, 1892.

XVII.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

ON THE CUPRIAMMONIUM DOUBLE SALTS.

By Theodore William Richards and Hubert Grover Shaw.

Presented May 10, 1893.

In the course of an extended investigation upon the ammoniacal compounds of copper, undertaken with the hope of obtaining more light upon the vexed question of their structure, a new class of interesting compounds was discovered. The preliminary notice of these compounds was published about a year ago;* but since that time several new ones have been added to the list. It is the object of this paper more fully to describe all of these substances, so far as they have been studied.

The generic feature of the new class is the fact that two different acids — a halogen and an organic acid radical — are united at the same time to the ordinary cupriammonium group. Below are tabulated the formulæ of the compounds, the preparation, properties, and analyses of which are described in the work which follows: —

(1.) $Cu(NH_3)_2BrC_2H_3O_2$.

(2.) $Cu(NH_3)_2ClC_2H_3O_2 \cdot H_2O$.

(3.) $[Cu(NH_3)_2ClC_2H_3O_2]_2 \cdot 3\,NH_4C_2H_3O_2 + 7\,H_2O$.

(4.) $Cu(NH_3)_2BrCHO_2$.

Besides these compounds two others, which appeared as by-products of the investigation, are worthy of description: —

(5.) $CuCl_2 \cdot 2\,NH_4C_2H_3O_2$.

(6.) $3\,CuBr_2 \cdot 10\,NH_3$.

* Theodore W. Richards, Berichte der deutsch. chem. Gesellsch., 1892, p. 1492. Since the publication of this paper, F. Foerste has announced the discovery of cupriammonium acetate (Ber. d. ch. Ges., 1892, XXV. 3416).

1. *Cupriammonium Acetobromide,*
$Cu(NH_3)_2BrC_2H_3O_2$.

This compound is formed with great ease whenever cupric bromide is treated with alcohol and saturated ammonia water, and the mixture is nearly neutralized with strong acetic acid. For example, five grams of cupric bromide were shaken with ten cubic centimeters of alcohol and the like volume of saturated ammonia water, until all of the copper was converted into cupriammonium bromide. The bright blue precipitate was then immediately dissolved in sixty or seventy cubic centimeters additional of alcohol, and sixteen cubic centimeters of strong acetic acid. Upon cooling the solution, and allowing it slowly to evaporate in the air, large brilliant deep-blue crystals, which apparently belong to the monoclinic system, slowly separated.*

The same substance may be obtained in a similar manner from cupric acetate and ammonic bromide, after treating with ammonia and afterwards with acetic acid.

The new compound is only very slightly soluble in pure alcohol, and is decomposed at once by water into impure cupric hydroxide, ammonic acetate and ammonic bromide. The cupric hydroxide contains large amounts of basic cupric bromide and acetate.

The only satisfactory solvent for it seems to be a strong aqueous solution of ammonic acetate and bromide, containing more or less alcohol. By this singular mixture the compound is not decomposed, even at 70° or 80° C. Acids of course at once decompose and dissolve cupriammonium acetobromide, and alkalies upon boiling set free ammonia and precipitate cupric oxide as usual. The crystals are fairly permanent in the air; they are singularly brittle and rather light, possessing a specific gravity of 2.134.

In the analysis of the compound, copper was determined electrolytically after evaporation with sulphuric and nitric acids; and the bromine and ammonia were determined as usual. The accurate determination of the acetic acid was a much harder task. Distillation with phosphoric acid, according to the method recommended by Fresenius,† is not very satisfactory because of the great expenditure of time which it requires, and the fact that traces of hydrobromic and phosphoric acids are always found in the distillate. Usually the two acids were precipitated together from the neutralized distillate, and the

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* T. W. Richards, Ber. d. ch. Ges., 1890, p. 3791.

† Zeit. für Analytische Chem., V. 315, and XIV. 172.

result was calculated as argentic bromide; but in some cases they were determined separately. The presence of phosphoric acid in the distillate is especially unfortunate, because of the uncertainty which it introduces in the end point of the alkalimetric reaction.

On the other hand, quantitative combustion after the usual method, and calculation of the acetic acid from the carbon dioxide formed, is not easy because of the presence of the large amount of bromine.

Analyses of $Cu(NH_3)_2BrC_2H_3O_2$.

I. 0.0685 gr. of the substance yielded 0.01865 gr. of copper upon electrolysis.

II. 0.1446 gr. of the substance distilled with caustic potash required 12.16 c.c. of a decinormal acid solution for neutralization.

III. 0.08485 gr. of the substance yielded 0.06705 gr. of argentic bromide.

IV. 0.3173 gr. of the substance yielded 0.2518 gr. of argentic bromide.

V. The distillate from a mixture of phosphoric acid and 0.2311 gr. of the substance required 10.11 c.c. of decinormal alkali for neutralization. Approximately corrected for the alkalimetric equivalent of the argentic phosphate and bromide obtained from the distillate this amount becomes 9.90 c.c.

Many other analyses were made of subsequent preparations, in order to be sure of the identity of the crystals prepared in different ways. It is considered unnecessary to publish these, since they agreed essentially with those given above.

No.	Copper.	Ammonia.	Bromine.	$C_2H_3O_2$.
I.	27.23			
II.		14.85		
III.			33.63	
IV.			33.78	
V.				25.27
Average,	27.23	14.85	33.70	25.27

Average Results.

	Calculated for $Cu(NH_3)_2BrC_2H_3O_2$.	Found.
Copper	26.87	27.23
Ammonia	14.42	14.35
Bromine	33.79	33.70
Acetic Acid	24.92	25.27
	100.00	100.35

2. *Ammon-Cupriammonium Acetochloride,*
$Cu(NH_3)_3ClC_2H_3O_2 . H_2O$.

Almost any mixture which brings together in concentrated solution copper, chlorine, much acetic acid, and an excess of ammonia yields ammon-cupriammonium acetochloride upon the addition of alcohol. The substance consists of brilliant blue scales, having a pearly lustre. These crystals lose ammonia and water slowly upon exposure to the air, with marked alteration of color; they are decomposed by water, a small amount of the copper going into solution. For analysis the crystals were pressed between filter paper as rapidly as possible. A bromine compound similar in every respect to this one has been prepared, and will form the subject of a future communication.

Analyses of Ammon-Cupriammonium Acetochloride.

I. 0.2524 gr. of the substance yielded on electrolysis 0.0698 gr. of copper.

II. 0.2273 gr. of the substance yielded 0.0634 gr. of copper.

III. 0.2875 gr. of the substance yielded 0.0808 gr. of copper.

IV. 0.1337 gr. of the substance required on distillation 17.37 c.c. of decinormal acid to neutralize the ammonia volatilized.

V. 0.1554 gr. of the substance required in the same way 20.17 c.c. of acid.

VI. 0.0979 gr. of the substance required 12.56 c.c. of decinormal acid.

VII. 0.2708 gr. of substance yielded 0.1704 gr. of argentic chloride.

VIII. 0.2696 gr. of substance yielded 0.1700 gr. of argentic chloride.

IX. 0.1926 gr. of the substance yielded upon distillation with phosphoric acid a distillate requiring 8.94 c.c. of decinormal baric hydroxide for neutralization with phenol phthalein. This liquid yielded 0.0116 gr. of argentic chloride, containing traces of argentic phosphate, which amount is equivalent to about 0.81 c.c. of decinormal acid. Hence the acetic acid in the distillate must have required 8.13 c.c. of the alkaline solution.

X. 0.2215 gr. of substance required upon distillation 10.38 c.c. of baric hydrate, of which 0.66 were required to neutralize the hydrochloric acid corresponding to 0.0096 gr. of argentic chloride obtained from the neutralized distillate (10.38 — 0.66 = 9.72).

No.	Copper.	Ammonia.	Chlorine.	$C_2H_3O_2$.
I.	27.65			
II.	27.89			
III.	28.17			
IV.		22.16		
V.		22.14		
VI.		21.89		
VII.			15.56	
VIII.			15.59	
IX.				24.91
X.				25.90
Average,	27.90	22.06	15.57	25.40

The averaged results are given below.

	Calculated for $Cu(NH_3)_2ClC_2H_3O_2 . H_2O$.	Found.
Copper	27.98	27.90
Ammonia	22.53	22.06
Chlorine	15.60	15.57
Acetic Acid	25.97	25.40
Water (by difference)	7.92	9.07
	100.00	100.00

3. *Complex* Cupriammonium Acetochloride,* $[Cu(NH_3)_2ClC_2H_3O_2]_2 . 3\,NH_4C_2H_3O_2 + 7\,H_2O$.

The complex cupriammonium acetochloride is obtained under conditions which would have been expected to produce the simple compound

* "Complex" is used here in default of a word more capable of describing the complexity of the compound. It is not intended to carry with it any tech-

enclosed in the brackets above. This simple compound, probably owing to its great solubility, we have been unable as yet to isolate. Whenever cupric chloride is treated with a great excess of concentrated ammonia water, the excess cautiously neutralized with glacial acetic acid, and the whole treated with alcohol and allowed to evaporate, great crystals of the complicated compound containing three molecules of ammonic acetate and probably seven of water to every two of cupriammonium acetochloride always separate out. The addition of somewhat more acetic acid in this case constitutes the sole difference between the methods of preparing this compound and the preceding. In the former case an excess of ammonia was required.

The crystals of the complex salt are of a most brilliant blue with a tinge of violet, and may be obtained of almost any size. They dissolve in very small amounts of water without apparent decomposition, but larger amounts of water decompose them. The new compound readily loses water and ammonic acetate in the air, and is converted into a pale green powder, which remains to be investigated. Over caustic potash in a desiccator, on the contrary, it is soon converted into a pale violet powder with a very sudden loss of weight. After the sudden decrease has stopped a slower decrease continues, without change of color, and the composition of the powder constantly approaches that of the simple cupriammonium acetochloride. Its complete conversion into this compound we have not yet been able to accomplish; and regarding the exact nature of the compounds which are marked by the irregular decrease in weight we have as yet nothing to say.

For analysis the crystals were pressed between filter paper. The possible causes of error from decomposition on the one hand, and the adhesion of mother liquor on the other, were guarded against as much as possible. Nevertheless these causes of error are undoubtedly responsible for the not unreasonable variations noticeable in the analytical results; for the three specimens of crystals analyzed were undoubtedly identical.

Analyses of Complex Cupriammonium Acetochloride.

I. 0.2404 gr. of the substance yielded on electrolysis 0.0411 gr. of copper.

II. 0.2446 gr. of the substance yielded on electrolysis 0.0419 gr. of copper.

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nical meaning with regard to the structure of the molecule. Indeed, the names of all the compounds described in this paper are far from satisfactory to us; they would be thrown out very gladly if better ones could be found.

III. 0.2772 gr. of the substance yielded on electrolysis 0.0476 gr. of copper.

IV. 0.1418 gr. of the substance yielded on distillation enough ammonia to neutralize 13.25 c.c. of decinormal acid.

V. 0.1403 gr. of the substance required on distillation 13.24 c.c. of decinormal acid.

VI. 0.1895 gr. of the substance required on distillation 17.79 c.c. of decinormal acid.

VII. 0.1472 gr. of the substance required on distillation 14.19 c.c. of decinormal acid.

VIII. 0.2319 gr. of the substance yielded 0.0895 gr. of argentic chloride.

IX. 0.2244 gr. of the substance yielded 0.0870 gr. of argentic chloride.

X. 0.1679 gr. of the substance gave on combustion 0.0998 gr. of carbon dioxide.

No.	Copper.	Ammonia.	Chlorine.	$C_2H_3O_2$.
I.	17.10			
II.	17.13			
III.	17.17			
IV.		15.95		
V.		16.11		
VI.		16.03		
VII.		16.46		
VIII.			9.54	
IX.			9.59	
X.				39.95
Average	17.13	16.16	9.57	39.95

A fourth sample, which had a similar appearance, was found to contain 17.61 per cent of copper and 9.94 of chlorine. This had probably begun to lose water and ammonic acetate. A finely powdered specimen kept for eleven months over sodic hydrate was found to con-

tain 25.8 per cent of copper and 14.35 of chlorine. Since the theoretical percentages corresponding to $Cu(NH)_2ClC_2H_3O_2$ are respectively 33.08 and 18.45, it is clear that the excess of ammonic acetate had not been wholly decomposed during the long exposure. Further experiments in this direction will be made in the near future.

Results.

	Calculated for $Cu_2(NH_3)_4Cl_2(C_2H_3O_2)_5(NH_4)_3 7 H_2O$.	Found.
Copper	17.12	17.13
Chlorine	9.55	9.57
Ammonia	16.08	16.16
$C_2H_3O_2$	39.73	39.95

4. *Cupriammonium Formibromide,* $Cu(NH_3)_2BrCHO_2$.

Cupriammonium formibromide is made after a method essentially similar to that employed in making the corresponding compound of acetic acid. The salt is more difficult to obtain in a pure state; but any reasonably concentrated solution containing bromine, copper, much formic acid, and ammonia in very slight excess, will deposit the deep "robin's egg" blue crystals of the desired salt upon the addition of alcohol. The possibility of the formation of basic salts of copper is diminished if the excess of ammonia is added after the addition of the alcohol. The salt possesses no unexpected properties, except that the color of the short needles is much less brilliant and crude than that of cupriammonium acetobromide.

A similar compound containing chlorine instead of bromine has been prepared, and analyzed with results which were sufficiently accurate to show the identity of the compound; but it was thought desirable to study more carefully the conditions necessary for its preparation in a pure state before publishing the results. Moreover, a more complex formibromide of most interesting aspect and composition has been made. This substance also awaits further study.

Analyses of Cupriammonium Formibromide.

I. 0.2192 gr. of the substance gave on electrolysis 0.0621 gr. of copper.

II. 0.2164 gr. of the substance yielded on electrolysis 0.0618 gr. of copper.

III. 0.1386 gr. of the substance yielded a distillate of ammonia which required for neutralization 12.32 c.c. of decinormal acid.
IV. Similarly 0.1180 gr. of the substance required 10.46 c.c. of decinormal acid.
V. 0.1599 gr. of the substance gave 0.1371 gr. of argentic bromide.
VI. 0.2414 gr. of the substance gave 0.2063 gr. of argentic bromide.
VII. 0.1678 gr. of the substance gave 0.1429 gr. of argentic bromide.
VIII. 0.2062 gr. of the substance yielded on combustion 0.0403 gr. of carbon dioxide.
IX. 0.2435 gr. of the substance yielded on combustion 0.0469 gr. of carbon dioxide.

No.	Copper.	Ammonia.	Bromine	Formic Acid, CHO_2.
I.	28.30			
II.	28.56			
III.		15.17		
IV.		15.13		
V.			36.49	
VI.			36.37	
VII.			36.24	
VIII.				19.93
IX.				19.70
Average,	28.43	15.15	36.37	19.80

These analyses were made from several different samples (especially V., VI., and VII., which were all different), and hence they prove the definiteness of the compound. The averaged results are given below.

	Calculated for $Cu(NH_3)_2BrCHO_2$.	Found.
Copper	28.56	28.43
Ammonia	15.33	15.15
Bromine	35.90	36.37
CHO_2	20.21	19.80
	100.00	99.75

5. *Cupric Ammonic Acetochloride,* $CuCl_2 . 2 NH_4C_2H_3O_2$.

Upon several occasions during the investigation just described, when concentrated solutions of approximately equivalent amounts of cupric chloride and ammonic acetate had been allowed to evaporate together, especially with addition of alcohol, bright green almost cubical crystals separated. These crystals were sometimes found to be mixed with small amounts of ammonic chloride, and sometimes almost pure. The substance is a double salt, and not a cupriammonium compound; hence it dissolves in water without apparent decomposition. The purest crystals gave the following analytical results.

Analyses of Cupric Ammonic Acetochloride.

I. 0.3132 gr. of the substance gave 0.0689 gr. of copper.
II. 0.2649 gr. of the substance gave 0.0585 gr. of copper.
III. 0.1180 gr. of the substance gave 0.1181 gr. of argentic chloride.
IV. 0.2091 gr. of the substance gave 0.2150 gr. of argentic chloride.
V. 0.2121 gr. of the substance yielded enough ammonia to require 14.47 c.c. of decinormal acid.
VI. 0.2158 gr. of the substance required 14.20 c.c. of acid.
VII. 0.1930 gr. of the substance required 13.83 c.c. of acid.
VIII. 0.2648 gr. of the substance gave 0.1633 gr. of carbon dioxide.

No.	Copper.	Chlorine.	Ammonium.	$C_2H_3O_2$.
I.	22.00			
II.	22.09			
III.		24.75		
IV.		25.35		
V.			12.34	
VI.			11.88 (?)	
VII.			12.98	
VIII.				41.35
Average,	22.05	25.05	12.40	41.35

	Calculated for $Cu(NH_4)_2Cl_2 (C_2H_3O_2)_2$.	Found.
Copper	22.03	22.05
Chlorine	24.56	25.05
Ammonium	12.52	12.40
Acetic Acid	40.89	41.35
	100.00	100.85

6. *Tetrammon-Tricupriammonium Bromide,* $3\,Cu(NH_3)_2Br_2 \,.\, 4\,NH_3$.

Long ago Rammelsberg* described two compounds of ammonia and cupric bromide, to one of which, consisting of dark green crystals, he ascribed the formula $CuBr_2 \,.\, 3\,NH_3$; and to the other, consisting of a bright blue powder, he ascribed the formula $CuBr_2 \,.\, 5\,NH_3$. Recent investigation † has shown that the latter of the two substances must have been in reality $CuBr_2 \,.\, 6\,NH_3$, which had lost some of its very loosely combined ammonia by exposure to the air. The same investigation brought to light an olive-green substance having the formula $Cu(NH_3)_2Br_2$.

Repeated attempts were made at the same time to obtain Rammelsberg's first substance. The product of these trials invariably consisted of deep indigo, almost black crystals, which contained noticeably more ammonia than the amount required by Rammelsberg's formula. These deep blue crystals are best obtained by adding very cautiously strong hydrobromic acid to a mixture of cupric bromide, alcohol, and just enough aqua ammonia to keep all the copper in solution. Upon the addition of enough acid to neutralize the ammonia, the crystals — which are almost insoluble in alcohol — begin to form.

Upon exposure to the air in a moist state these crystals lose ammonia rather rapidly; but when dry they are much more stable. Gentle heat (160°) readily converts them completely into the olive-green $Cu(NH_3)_2Br_2$, which still retains the crystalline form of the more complex salt. It is not impossible that Rammelsberg's green crystals consisted originally of the indigo-colored substance, which had lost superficially a little of its ammonia.

Tetrammon-tricupriammonium bromide is decomposed by water, a noticeable amount of copper going into solution in the form of a sol-

* Pogg. Annalen, LV. 246.

† T. W. Richards, Ber. d. ch. Ges., 1890, p. 3790.

uble compound containing proportionally more ammonia than the original substance. The reaction which takes place may possibly be represented somewhat as follows: —

$$Cu_3(NH_3)_{10}Br_6 + 4\,H_2O$$
$$= [Cu(NH_3)_6Br_2 + 4\,NH_4Br + Aq] + 2\,Cu(OH)_2.$$

The amount of water present undoubtedly determines to a large extent the exact nature of the cupriammonium compound which remains undecomposed.

A great number of analyses of the indigo salt were made; partly because of the unusual nature of the formula which they indicated; and partly because the crystals, constantly appearing under many varying conditions in the work which has just been described, needed identification.

Analyses of $Cu_3(NH_3)_{10}Br_6$.

I. 0.4730 gr. of the substance yielded 0.1075 gr. of copper.
II. 0.4540 gr. of the substance yielded 0.1033 gr. of copper.
III. 0.2614 gr. of the substance yielded 0.0594 gr. of copper.
IV. 0.4269 gr. of the substance yielded 0.5721 gr. of argentic bromide.
V. 0.4084 gr. of the substance yielded 0.5476 gr. of argentic bromide.
VI. 0.2884 gr. of the substance yielded 0.3861 gr. of argentic bromide.
VII. 0.1776 gr. of the substance yielded an amount of ammonia requiring 20.67 c.c. of decinormal acid for neutralization.
VIII. 0.1245 gr. of the substance required 14.77 c.c. of the same acid.
IX. 0.1099 gr. of the substance required 12.71 c.c. of the same acid.
X. 0.1288 gr. of the substance required 15.20 c.c. of the same acid.
XI. 0.1175 gr. of the substance required 13.85 c.c. of the same acid.

No.	Copper.	Bromine.	Ammonia.
I.	22.73		
II.	22.75		
III.	22.72		
IV.		57.03	
V.		57.06	
VI.		56.97	
VII.			19.86
VIII.			20.25
IX.			19.74
X.			20.14
XI.			20.19
Average,	22.78	57.02	20.06

Result.

	Calculated for $CuBr_2 3 NH_3$.	Calculated for $(CuBr_2)_3(NH_3)_{10}$.	Found.
Copper	23.15	22.68	22.73
Bromine	58.21	57.03	57.02
Ammonia	18.64	20.29	20.06
	100.00	100.00	99.81

It is evident that this paper is merely an introduction to the possibilities in the direction indicated. Not only have other compounds of the same acids been already discovered, but many other acids, notably hydriodic, lactic, sulphocyanic, etc., show that they are capable of forming similar compounds. Moreover, the substituted ammonias may apparently take the place of the simple substance in most of the compounds. A few of these preparations are to be seen in the University exhibit at the World's Columbian Exhibition. The study of all these interesting substances will be continued in the immediate future at this Laboratory.

XVIII.

NOTES ON THE OXIDES CONTAINED IN CERITE, SAMARSKITE, GADOLINITE, AND FERGUSONITE.

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Presented June 14, 1893.

IN the present paper I have brought forward a number of observations and analyses which I hope will be of service to those who are engaged in the study of the rarer earths. The subject is one of such extreme difficulty, that even the results of an imperfect study may have value.

For the material which I have employed I have been chiefly indebted to Dr. Waldron Shapleigh, Chemist to the Welsbach Incandescent Light Company, by whom I have been liberally supplied with various preparations in a state of considerable purity. I have also to make my acknowledgments to Professor Everhart, from whom I have received a considerable quantity of gadolinite from the well known locality in Llano County, Texas. The material given me by Dr. Shapleigh consisted in part of beautiful crystalline double nitrates of the earths and ammonium, and in part of crude oxides. The double nitrates contained only the earths present in cerite, and for the most part only Ce_2O_3, Ln_2O_3, Ps_2O_3, and Nd_2O_3, with very small relative quantities of Y_2O_3, and traces only of other earths. In converting the crude oxides into sulphates it is best to sift the fine powder slowly upon the surface of cold dilute sulphuric acid. The sulphates are then formed at once as fine crystalline powders free from hard lumps. Another method sometimes applicable with advantage consists in mixing the oxides with an excess of ammonic sulphate, and then igniting slowly in porcelain crucibles, which are to be heated in a muffle to low redness until vapors are no longer given off. The sulphates then present a beautiful snow-white soft crystalline powder, and readily form saturated solutions with cold water. In all work with the rare earths, oxalates from their insolubility play a very important part. They may, as all chemists know, be readily converted into sulphates by treatment with sul-

phuric acid and careful expulsion of the excess of this last by heat. I have found it more convenient to mix the oxalate intimately with an excess of ammonic sulphate and heat carefully in a muffle, as in the last case. The resulting sulphates are perfectly soluble without packing together if sifted upon the surface of cold water. They are also perfectly neutral. The oxalates may also be converted into chlorides by mixing them intimately with ammonic chloride and igniting the mixture in a muffle very gently.

Determinations of mean atomic mass are now always employed in the study of the mixtures of oxides which present themselves in the attempt to effect separations. Very accurate results are obtained by the usual method of converting a weighed quantity of oxides into the equivalent weight of sulphates by treatment with sulphuric acid and subsequent careful ignition. Probably this could be done more conveniently, and in less time, by igniting the oxides in porcelain crucibles in a muffle, after mixing carefully with ammonic sulphate, but upon this point I have made no quantitative experiments.

In all my work I have employed the analysis of the oxalates as convenient and accurate. It is, however, necessary to insist upon several points of detail. In the first place I remark that the preparation of perfectly homogeneous mixtures of the oxalates requires much care. It is best to precipitate by a hot dilute solution of oxalic acid added slowly in small but distinct excess to a hot dilute solution of the mixed chlorides or nitrates. The precipitated oxalates are then to be thoroughly washed by decantation with hot distilled water. This requires in general a large quantity of water, and must be continued until the washings contain no trace of oxalic acid and give no cloudiness with ammonia. Auer von Welsbach's process, which consists in adding a very dilute solution of the nitrates (or chlorides) to a hot dilute solution of oxalic acid, gives the oxalates in a state of very fine subdivision and perfectly free from hard masses. The mixed washings on saturation with ammonia sometimes give a precipitate of oxalates, though in small quantity. These oxalates may be washed and mixed with the main portion. The mass is to be dried upon a water-bath, and then thoroughly mixed in a dry mortar. Only in this manner is it possible to obtain a mass of oxalates sufficiently homogeneous to yield corresponding results when different portions are analyzed. The determination of the mean atomic mass in the oxalates prepared as above involves only the determination of the percentages of oxide R_2O_3 and of C_2O_3, the water present being of course without influence. Here I may remark that, as has doubtless been observed by other

chemists, the last portions of water require a very high temperature for expulsion. The details of the method which I employ are as follows. From 0.5 gr. to 1 gr. of the oxalate is to be gently heated until the greater part of the water and carbonic dioxide have been driven off, and then at a full red heat for fifteen to twenty minutes with a blast lamp to a constant weight. During ignition the crucible is best placed at an angle, and partly uncovered to permit free access of air. The mixed oxides do not retain a weighable amount of carbonic dioxide. To determine C_2O_3, from 0.3 gr. to 0.4 gr. of the oxalate are to be weighed into a 250 c.c. flask; 20 c.c. of water and 30 c.c. of dilute sulphuric acid, 1 : 6 by volume, are then to be added and the flask is to be gently heated upon a sand-bath until the solution is complete, when the hot liquid is to be titrated with carefully standardized permanganate. The following analyses will show the correspondence between the results obtained by the above described method and those obtained by the sulphate process. In an oxalate from a perfectly colorless nitrate of lanthanum and ammonium sent me by Dr. Shapleigh, —

(1)	0.3344 gr.	gave	0.1009 gr.	C_2O_3	=	30.15	per cent.
(2)	0.3274 gr.	"	0.09895 gr.	"	=	30.07	"
(3)	0.3726 gr.	"	0.1120 gr.	"	=	30.08	"
(4)	0.3485 gr.	"	0.1050 gr.	"	=	30.11	"
(5)	0.5931 gr.	"	0.2706 gr.	R_2O_3	=	45.61	"
(6)	0.5977 gr.	"	0.2728 gr.	"	=	45.64	"

The means are 30.10 per cent C_2O_3, and 45.625 per cent R_2O_3. The mean atomic mass calculated from the above is 139.70. Dr. Shapleigh found by the sulphate method 139.75, 139.72, 139.67, mean 139.71.

The necessity of thoroughly mixing the oxalates will appear from the following analyses made with oxalates simply washed and dried: —

(7)	0.3549 gr.	gave	0.1274 gr.	C_2O_3	=	35.88	per cent.
(8)	0.3697 gr.	"	0.1316 gr.	"	=	35.59	"
(9)	0.3807 gr.	"	0.1382 gr.	"	=	36.29	"
(10)	0.6550 gr.	"	0.2869 gr.	R_2O_3	=	43.79	"
(11)	0.6125 gr.	"	0.2699 gr.	"	=	44.07	"

The same oxalates carefully mixed in a mortar were also analyzed for comparison: —

(12)	0.3357 gr.	gave	0.1213 gr.	C_2O_3	= 36.16	per cent.
(13)	0.3856 gr.	"	0.1393 gr.	"	= 36.13	"
(14)	0.6538 gr.	"	0.2906 gr.	R_2O_3	= 44.45	"
(15)	0.7074 gr.	"	0.3145 gr.	"	= 44.46	"

The analyses leave no doubt whatever as to the necessity of carefully mixing the precipitated oxalates. They also show that in determinations of atomic mass by the sulphate method both oxalates and oxides should be well ground up to secure homogeneity. It has been shown that the oxalate and sulphate methods executed with proper care give equally accurate results. Each has its advantages, and in this respect there is but little choice. As the study of the rarer earths as now conducted usually depends more or less upon the properties of the double salts which they form with potassic and sodic sulphates, it may be well to call attention to facts not, I believe, noticed in printed papers, though doubtless recognized. The first is that the earths in the double sulphates may be converted directly into oxalates by boiling the sulphates with chlorhydric and oxalic acids, and then diluting with much water. The second fact is that oxalates obtained in this way, as from any alkaline solutions, should always be converted into oxides by ignition. These should then be dissolved in chlorhydric acid, again precipitated by oxalic acid, and the oxalates thoroughly washed.

In determining atomic masses by either the sulphate or oxalate method, the assumption is tacitly made that all the oxides taken for analysis are of the type R_2O_3. This is not true when cerium is present, as in that case a portion at least of this metal is present as CeO_2 after ignition. Higher oxides than R_2O_3 are also present to some extent, at least when praseodymia and neodymia are mixed with ceria, or even when this last oxide is not present. Ceric oxide is not reduced by a full red heat to cerous oxide, or even by a current of hydrogen, at least in a crucible. The error committed is not, however, large when we consider the cerium as Ce_2O_3 instead of Ce_2O_4, and is still less in the cases of the other oxides. When great accuracy is necessary, it may be well to remove the four cerite oxides by means of potassic or sodic sulphate before determining the atomic mass.

In a number of analyses I determined the percentage of oxides by simply igniting the oxalate with a weighed quantity of pure sodic tungstate. This method gives very accurate results, but, as pure sodic tungstate must always be specially prepared in the laboratory, is not to be greatly recommended. Ceric oxide is not reduced

to cerous oxide by heating with the tungstate to a red heat for some time. I may here state that a test for ceria more delicate than that which I gave many years since (PbO_2 and NO_3H) is obtained by employing the oxide of bismuth, Bi_2O_4, in place of plumbic oxide.

With these preliminaries I proceed to special methods of separating the mixed oxides. A series of experiments was first made to determine to what extent differentiation is effected by successive partial precipitations by oxalic acid. The method is of course not new, but, so far as I know, it has not been tested by quantitative analyses, and no attempt has been made to determine the rate of change. The material used in this case was a mixture of sulphates, the sulphate of neodymium being present in largest quantity. Thoric and other oxides in less quantity were also present. The material was obtained from Dr. Shapleigh in the form of oxides. After careful purification the atomic mass of the oxides was first determined: —

(16)	0.5622 gr.	gave	0.1715 gr.	C_2O_3	= 30.50	per cent.
(17)	0.4782 gr.	"	0.1458 gr.	"	= 30.50	"
(18)	0.4355 gr.	"	0.1326 gr.	"	= 30.47	"
(19)	0.6100 gr.	"	0.2778 gr.	R_2O_3	= 45.55	"
(20)	0.6904 gr.	"	0.3141 gr.	"	= 45.50	"

The analyses give as the atomic mass 137.25. A portion of the oxides was then converted into sulphates, and the number of cubic centimeters of a solution of oxalic acid required for complete precipitation, determined by experiment with a sufficiently close approximation. A solution of the sulphates having a very fine rose-red color was then precipitated in five successive additions of equal volumes of a solution of oxalic acid. After each addition of the acid the resulting oxalate was filtered off and washed. The washings were then added to the filtrate. It will be seen that in this way the bulk of the solution increased before each precipitation after the first. The results are as follows: —

I.	(21)	0.3126 gr.	gave	0.0941 gr.	C_2O_3	= 30.52	per cent.
	(22)	0.3410 gr.	"	0.1042 gr.	"	= 30.54	"
	(23)	0.5773 gr.	"	0.2820 gr.	R_2O_3	= 48.84	"
	(24)	0.5856 gr.	"	0.2855 gr.	"	= 48.75	"

Atomic mass 148.60.

II.	(25)	0.3563 gr. gave	0.1114 gr.	C_2O_3	= 31.26	per cent.
	(26)	0.3500 gr. "	0.1091 gr.	"	= 31.20	"
	(27)	0.6848 gr. "	0.3317 gr.	R_2O_3	= 48.43	"
	(28)	0.6664 gr. "	0.3223 gr.	"	= 48.37	"
		Atomic mass 143.35.				
III.	(29)	0.3500 gr. gave	0.1113 gr.	C_2O_3	= 31.78	"
	(30)	0.3127 gr. "	0.09936 gr.	"	= 31.77	"
	(31)	0.6859 gr. "	0.3345 gr.	R_2O_3	= 48.75	"
	(32)	0.7087 gr. "	0.3447 gr.	"	= 48.65	"
		Atomic mass 141.55.				
IV.	(33)	0.3350 gr. gave	0.1042 gr.	C_2O_3	= 31.12	"
	(34)	0.3410 gr. "	0.1060 gr.	"	= 31.09	"
	(35)	0.6369 gr. "	0.2958 gr.	R_2O_3	= 46.44	"
	(36)	0.6468 gr. "	0.3004 gr.	"	= 46.45	"
		Atomic mass 137.25.				
V.	(37)	0.2042 gr. gave	0.06864 gr.	C_2O_3	= 33.62	"
	(38)	0.2031 gr. "	0.06828 gr.	"	= 33.62	"
	(39)	0.3045 gr. "	0.1409 gr.	R_2O_3	= 46.26	"
	(40)	0.3400 gr. "	0.1569 gr.	"	= 46.14	"
		Atomic mass 124.40.				

The filtrate from the last portion of oxalates contained only traces of earths. The analyses show that the earths with the highest atomic masses are precipitated first by oxalic acid. The average rate of decrease of mean atomic mass is five units for each operation, but the rate is by no means uniform. The results prove that precipitated oxalates must be very carefully mixed mechanically before analysis when more than one earth is present. The analyses also show that four fifths of the earths might have been precipitated at once by oxalic acid if the object had been to obtain yttria with the least outlay of time and labor, the atomic mass of the last fifth being 124.40.

Oxychlorides. — When the chlorides of the metals belonging to the cerium and yttrium groups, or, more generally stated, of the metals yielding the rarer earths, are carefully heated, oxychlorides are formed in greater or less proportion mixed with undecomposed chlorides. We may distinguish these as acid and basic chlorides. Water dissolves out the former very readily, and leaves nearly or quite colorless basic chlorides, which are, relatively at least, insoluble. I find that in this way the earths present are separated into two groups, and that by repeating the operation upon each group a second differentiation is

effected in each case. The process appears to deserve attention, and to compare very favorably with separation by means of basic nitrates. The details of this method are as follows.

The mixed oxides in as pure a state as possible are to be dissolved in a small excess of pure chlorhydric acid; the solution is then to be evaporated at first on a water-bath, and then on a sand-bath, until a thick syrup is obtained. This is to be transferred to a porcelain crucible, which is then to be heated gently in a muffle. The heat should not be allowed to exceed low redness. Much chlorhydric acid is given off during the heating, and a white mass remains which consists in part of a mixture of oxychlorides, and in part of unaltered chlorides. The mass is then to be treated with hot water in rather small portions at a time, the solution being poured off before each new addition. When the washing is nearly complete, the solution becomes turbid. The white insoluble mass and supernatant liquid are then to be evaporated to dryness, or to a thick syrup, after the addition of enough chlorhydric acid to effect complete solution. The liquid poured off and containing the soluble chlorides is also to be evaporated to dryness, but without addition of chlorhydric acid. We have then two separate portions, of which one, A, contains the soluble or relatively acid chlorides, and the other, B, the neutralized oxychlorides. Each of these portions is to be treated in the muffle as in the first case. In this manner two new basic chlorides, B_2 and B_3, and two new acid chlorides, A_2 and A_3, are obtained. The same processes are to be repeated as long as the material lasts. The atomic mass of the oxides taken must first be determined, and afterward the atomic masses of the portions A_1, A_2, A_3, etc., and B_1, B_2, B_3, etc. This enables us to determine the rate of change in the atomic masses produced by the successive operations. Of course it is only necessary to take a small portion of each product A_1, B_1, etc., for the determination of the atomic mass. The whole process will perhaps be rendered more clear by means of a diagram, and in illustration I shall select the results of actual work in a particular case. The starting point in this case was a mixture of oxides from Texas gadolinite having the atomic mass 107.5. The data are as follows: —

(41)	0.3577 gr.	gave	0.1357 gr.	C_2O_3	= 37.94	per cent.
(42)	0.3246 gr.	"	0.1228 gr.	"	= 37.81	"
(43)	0.3999 gr.	"	0.1515 gr.	"	= 37.86	"
(44)	0.6113 gr.	"	0.2814 gr.	R_2O_3	= 46.04	"
(45)	0.6670 gr.	"	0.3064 gr.	"	= 45.94	"
(46)	0.6303 gr.	"	0.2892 gr.	"	= 45.88	"

Atomic mass 107.5.

B_1 Left. Atomic mass 110.8.

(47) 0.6836 gr. gave 0.3289 gr. R_2O_3 = 48.11 per cent.
(48) 0.2344 gr. " 0.0904 gr. C_2O_3 = 38.57 "

A_1 Right. Atomic mass 94.75.

(49) 1.2740 gr. gave 0.4976 gr. R_2O_3 = 39.65 per cent.
(50) 0.2998 gr. " 0.1065 gr. C_2O_3 = 35.51 "

B_2 Left. Atomic mass 117.4.

(51) 0.4327 gr. gave 0.2157 gr. R_2O_3 = 49.84 per cent.
(52) 0.2860 gr. " 0.1089 gr. C_2O_3 = 38.07 "

A_2 Left. Atomic mass 98.35.

(53) 0.7897 gr. gave 0.3714 gr. R_2O_3 = 47.03 per cent.
(54) 0.3772 gr. " 0.1566 gr. C_2O_3 = 41.52 "

B_3 Left. Atomic mass 122.

(55) 0.5910 gr. gave 0.2803 gr. R_2O_3 = 47.43 per cent.
(56) 0.2023 gr. " 0.0710 gr. C_2O_3 = 35.09 "

A_3 Left. Atomic mass 102.8.

(57) 0.4472 gr. gave 0.2137 gr. R_2O_3 = 47.78 per cent.
(58) 0.3067 gr. " 0.1248 gr. C_2O_3 = 40.70 "

A_1 Right. Atomic mass 94.75.

(59) 1.2740 gr. gave 0.4976 gr. R_2O_3 = 39.05 per cent.
(60) 0.2998 gr. " 0.1065 gr. C_2O_3 = 35.51 "

A_2 Right. Atomic mass 91 65.

(61) 1.0032 gr. gave 0.3948 gr. R_2O_3 = 39.37 per cent.
(62) 0.5057 gr. " 0.1856 gr. C_2O_3 = 36.77 "

B_2 Right Atomic mass 98.6.

(63) 0.7353 gr. gave 0.3291 gr. R_2O_3 = 44.75 per cent.
(64) 0.3343 gr. " 0.1318 gr. C_2O_3 = 39.43 "

A_3 Right. Atomic mass 89.5.

(65) 0.4864 gr. gave 0.2146 gr. R_2O_3 = 44.12 per cent.
(66) 0.2212 gr. " 0.0929 gr. C_2O_3 = 42.00 "

B_3 Right. Atomic mass 92.35.

(67) 0.5183 gr. gave 0.2238 gr. R_2O_3 = 43.17 per cent.
(68) 0.2080 gr. " 0.0834 gr. C_2O_3 = 40.07 "

effected in each case. The process appears to deserve attention, and to compare very favorably with separation by means of basic nitrates. The details of this method are as follows.

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(43)	0.3999 gr.	"	0.1515 gr.	"	= 37.86	"
(44)	0.6113 gr.	"	0.2814 gr.	R_2O_3	= 46.04	"
(45)	0.6670 gr.	"	0.3064 gr.	"	= 45.94	"
(46)	0.6303 gr.	"	0.2892 gr.	"	= 45.88	"

Atomic mass 107.5.

B_1 Left. Atomic mass 110.8.

(47) 0.6836 gr. gave 0.3289 gr. R_2O_3 = 48.11 per cent.
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(51) 0.4327 gr. gave 0.2157 gr. R_2O_3 = 49.84 per cent.
(52) 0.2860 gr. " 0.1089 gr. C_2O_3 = 38.07 "

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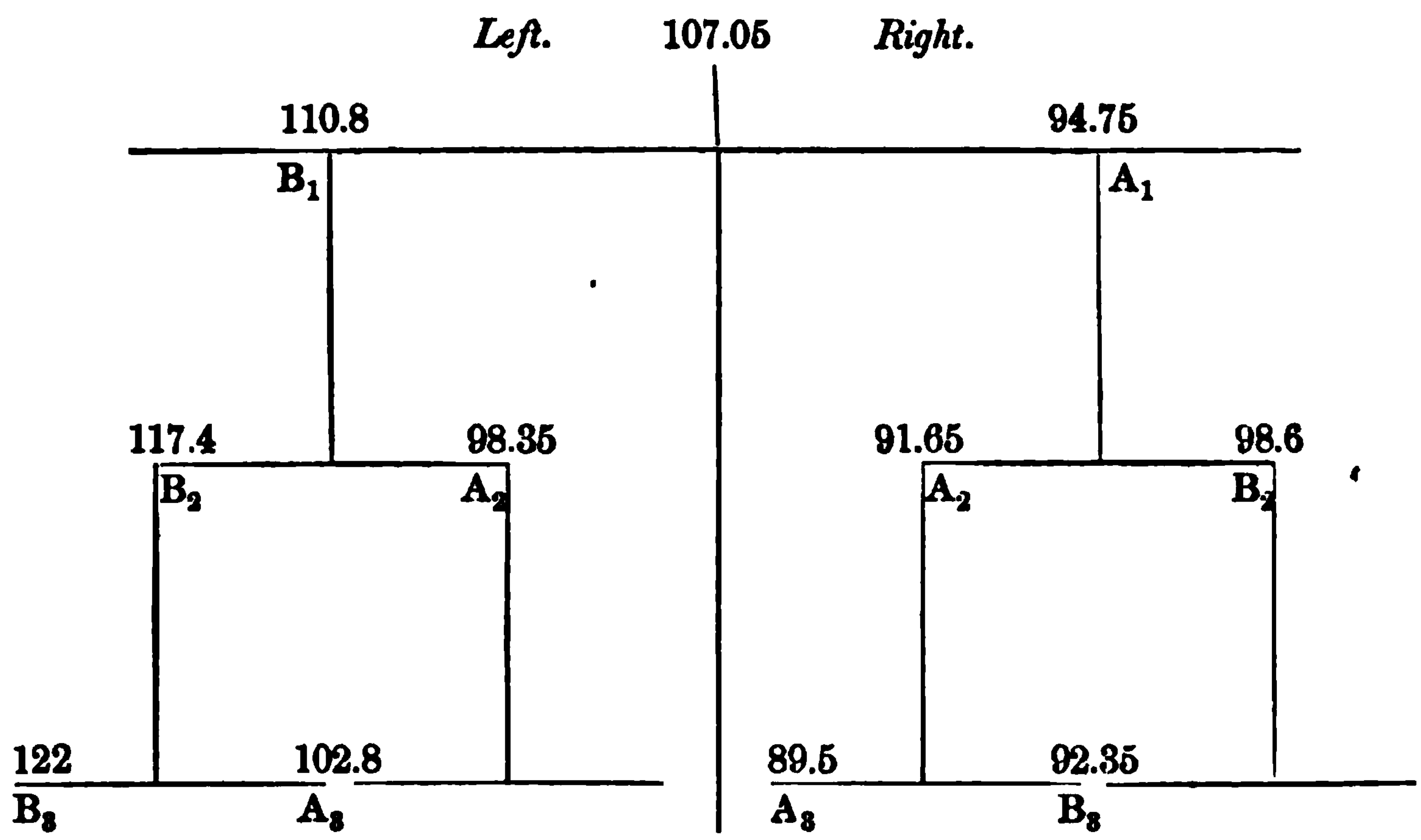
B_3 Right. Atomic mass 92.35.

(67) 0.5183 gr. gave 0.2238 gr. R_2O_3 = 43.17 per cent.
(68) 0.2080 gr. " 0.0834 gr. C_2O_3 = 40.07 "

The following diagram enables us to take in all the results at a glance.



It must be noted that in the above and on the diagram, B_1, B_2, B_3, etc. denote basic or oxychlorides; A_1, A_2, A_3, etc., neutral or relatively acid chlorides. The analyses were not pursued further because the material taken was exhausted by the separations accomplished. The examination of the results obtained in this particular case by the basic chloride process leads to interesting conclusions. In the first place, it will be remarked that the atomic masses of the insoluble basic chlorides increase with each successive separation into basic and acid chlorides, while the neutral or relatively acid chlorides give diminishing atomic masses. In the cases of these last, three successive operations give a nearly pure yttria, with atomic mass 89.5. The rate of increase of the atomic masses of the successive portions B_1, B_2, B_3, is about 5.3 units for each operation. The rate of decrease of the portions A_1, A_2, A_3, is about 2.6 units for each operation. It is not to be expected that perfectly uniform results will be obtained even when the process is applied to the same mixture of oxides, because the amount of separation into basic and acid chlorides by each operation must depend very much upon the temperature of the muffle and the length of time during which the heat is applied. In the second place, it must be noted that, while a very nearly pure yttria is obtained in three operations, this does not represent the whole quantity of the earth in the compound. It will also be seen that a decided advantage must be secured by making mixtures of the products hav-

ing nearly the same atomic masses, and then applying the method of separation to these.

Other applications of the method give, as I will now show, substantially similar results. The next substance examined was a mixture of oxides received from Dr. Shapleigh, and obtained from residual mother liquors of cerite and monazite salts. The oxide was dissolved in chlorhydric acid, and purified by a current of sulphydric acid. Of the mixed oxalates, —

(69)	0.5622 gr.	gave	0.1715 gr. C_2O_3	= 30.50	per cent.
(70)	0.4782 gr.	"	0.1458 gr. "	= 30.50	"
(71)	0.4355 gr.	"	0.1326 gr. "	= 30.47	"
(72)	0.6100 gr.	"	0.2778 gr. R_2O_3	= 45.55	"
(73)	0.6904 gr.	"	0.3141 gr. "	= 45.50	"

Atomic mass 137.25.

I also determined the mean atomic mass after separating the cerite earths by means of sodic sulphate in the usual manner. Of course some yttria went down with the double sulphates.

(74)	0.2440 gr.	gave	0.0946 gr. C_2O_3	= 38.77	per cent.
(75)	0.2438 gr.	"	0.0946 gr. "	= 38.80	"
(76)	0.4597 gr.	"	0.2146 gr. R_2O_3	= 46.68	"
(77)	0.3570 gr.	"	0.1668 gr. "	= 46.72	"

Atomic mass 106.05.

The oxides with atomic mass 106.05 were then treated by the oxychloride process.

Portion B_1 Left.

(78)	0.4027 gr.	gave	0.1505 gr. C_2O_3	= 37.38	per cent.
(79)	0.5204 gr.	"	0.1943 gr. "	= 37.35	"
(80)	0.6947 gr.	"	0.3250 gr. R_2O_3	= 46.78	"
(81)	0.9233 gr.	"	0.4323 gr. "	= 46.82	"

Atomic mass 111.3.

Portion B_2 Left.

(82)	0.4127 gr.	gave	0.1464 gr. C_2O_3	= 35.49	per cent.
(83)	0.3215 gr.	"	0.1142 gr. "	= 35.51	"
(84)	0.5885 gr.	"	0.2668 gr. R_2O_3	= 45.33	"
(85)	0.6205 gr.	"	0.2814 gr. "	= 45.35	"

Atomic mass 113.95.

Portion A_1 Right.

(86)	0.4332 gr.	gave	0.1630 gr.	C_2O_3	= 37.63	per cent.
(87)	0.3239 gr.	"	0.1217 gr.	"	= 37.57	"
(88)	0.6813 gr.	"	0.3062 gr.	R_2O_3	= 44.94	"
(89)	0.6749 gr.	"	0.3035 gr.	"	= 44.95	"

Atomic mass 105.1.

Portion A_2 Right.

(90)	0.3317 gr.	gave	0.1161 gr.	C_2O_3	= 35.02	per cent.
(91)	0.3216 gr.	"	0.1126 gr.	"	= 35.00	"
(92)	0.6800 gr.	"	0.2823 gr.	R_2O_3	= 41.52	"
(93)	0.6529 gr.	"	0.2709 gr.	"	= 41.50	"

Atomic mass 104.05.

B_2 Right.

(94)	0.3785 gr.	gave	0.1314 gr.	C_2O_3	= 34.73	per cent.
(95)	0.2882 gr.	"	0.0999 gr.	"	= 34.68	"
(96)	0.6187 gr.	"	0.2676 gr.	R_2O_3	= 43.25	"
(97)	0.6421 gr.	"	0.2770 gr.	"	= 43.24	"

Atomic mass 110.45.

A_2 Left.

(98)	0.3458 gr.	gave	0.1290 gr.	C_2O_3	= 37.31	per cent.
(99)	0.4089 gr.	"	0.1523 gr.	"	= 37.24	"
(100)	0.6892 gr.	"	0.3062 gr.	R_2O_3	= 44.43	"
(101)	0.5986 gr.	"	0.2660 gr.	"	= 44.44	"

Atomic mass 104.75.

A_3 Right.

(102)	0.3002 gr.	gave	0.1162 gr.	C_2O_3	= 38.73	per cent.
(103)	0.3251 gr.	"	0.1260 gr.	"	= 38.77	"
(104)	0.6667 gr.	"	0.3031 gr.	R_2O_3	= 45.44	"
(105)	0.7642 gr.	"	0.3478 gr.	"	= 45.51	"

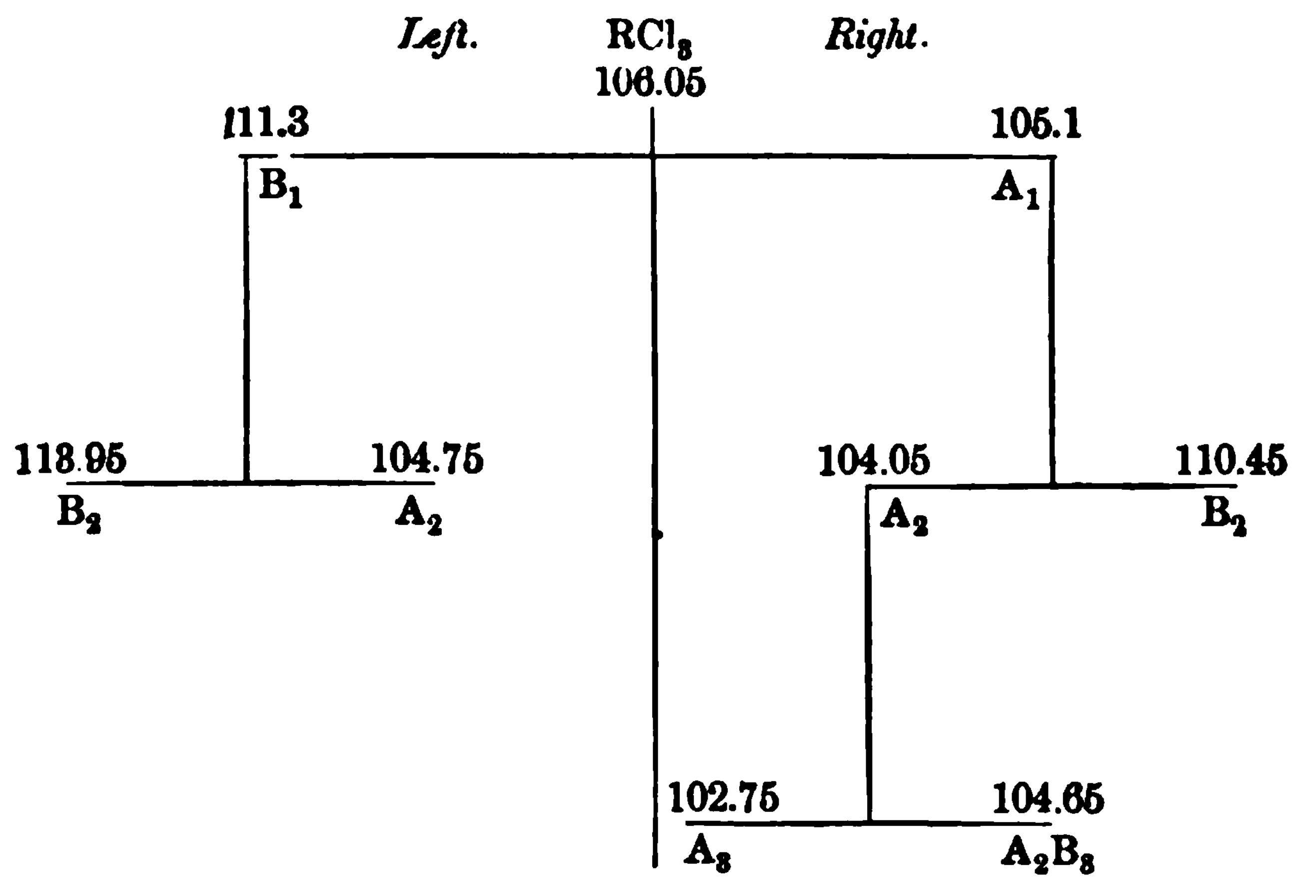
Atomic mass 102.75.

(106) A_2, B_3 Right.

(107)	0.3426 gr.	gave	0.1307 gr.	C_2O_3	= 38.16	per cent.
(108)	0.3401 gr.	"	0.1298 gr.	"	= 38.18	"
(109)	0.8197 gr.	"	0.3728 gr.	R_2O_3	= 45.46	"
(110)	0.7623 gr.	"	0.3467 gr.	"	= 45.47	"

Atomic mass 104.65.

These determinations exhausted the material employed. The following diagram brings together all the results.



The diagram in the case of the oxides from cerite and monazite shows very clearly that, as with the oxides from gadolinite, the atomic masses B_1, B_2, B_3 increase, while those of A_1, A_2, A_3 diminish, but at a different rate, perhaps, as already remarked, because the conditions were not precisely the same. It seems very desirable that similar experiments should be made with the basic nitrate process, which has been so much used, so as to determine which method gives results that converge most rapidly toward the atomic masses of pure oxides. Only in this manner can the relative values of the two methods be determined. I consider it probable that further experience with the oxychloride process will lead to a very material shortening of the process. I have employed for the most part porcelain crucibles holding about 130 c.c., but with larger muffles it would be easy to work up a kilogram of oxides at each operation. Also much is to be expected from a judicious mixture of the different products on the right and left having nearly the same atomic masses. All points fairly considered, I am I believe justified in offering the oxychloride process as worthy of further trial.

It appeared possible that basic bromides might be more advantageous than basic chlorides as means of differentiation, but the experiments made were not conclusive on this point. Observing the formation of beautiful well defined crystals when the oxides from gadolinite and the cerite and monazite residues were dissolved in chlorhydric or

bromhydric acid, and the solutions evaporated to a syrupy consistence, I examined two cases. The perfectly colorless and easily soluble crystals obtained from gadolinite earths free from cerite earths by chlorhydric acid after two successive crystallizations were analyzed.

(111)	0.3248 gr.	gave	0.1293 gr. C_2O_3	= 39.82	per cent.
(112)	0.3000 gr.	"	0.1450 gr. R_2O_3	= 48.34	"

The atomic mass is 107.10 so that the crystalline chlorides contained the earths in the same proportion in which they were obtained from gadolinite after separation of the cerite earths.

Precisely the same result was obtained with crystallized bromides prepared by dissolving the crude oxides from the cerite and monazite residues in bromhydric acid and evaporating. The beautiful colorless crystals were not quite free from the mother liquor. Of these crystals,

(113)	0.3418 gr.	gave	0.1064 gr. C_2O_3	= 31.11	per cent.
(114)	0.4266 gr.	"	0.1325 gr. "	= 31.07	"
(115)	0.6110 gr.	"	0.2879 gr. R_2O_3	= 47.13	"
(116)	0.6896 gr.	"	0.3293 gr. "	= 47.02	"

The atomic mass is 139.55, which is nearly the same as that obtained from the oxides directly, 137.25.

The mother liquor from the crystals was also analyzed.

(117)	0.3750 gr.	gave	0.1171 gr. C_2O_3	= 31.25	per cent.
(118)	0.3237 gr.	"	0.1015 gr. "	= 31.37	"
(119)	0.6752 gr.	"	0.3180 gr. R_2O_3	= 47.10	"
(120)	0.8150 gr.	"	0.3837 gr. "	= 47.08	"

The atomic mass corresponding is 138.45. From the above it appears that little, if anything, is gained by crystallization of the chlorides and bromides, at least in the cases cited.

The fact, that potassic and sodic sulphates which do not give precipitates of double sulphates in cold saturated solutions of certain earths often give crystalline precipitates on boiling, has doubtless been observed. I do not find, however, that such observations have been noted in published papers. The following analyses will serve to show that valuable results may sometimes at least be obtained by this process.

A quantity of oxides from Samarskite, sent me by Dr. Shapleigh, was dissolved in chlorhydric acid, and precipitated cold by an excess of potassic sulphate. After filtering off the double sulphates, sodic sulphate was added and the solution boiled. An abundant white crystalline salt was obtained. After washing with a little boiling water the double salt was dissolved in chlorhydric acid, and oxalic acid added after large dilution. The oxalates were converted into oxides and these redissolved in chlorhydric acid and again precipitated with oxalic acid. The oxalates were then analyzed.

(121) 0.2853 gr. gave 0.1217 gr. R_2O_3.
(122) 0.3889 gr. " 0.1660 gr. "
(123) 0.5558 gr. " 0.2256 gr. C_2O_3.

Atomic mass 89.55, which does not sensibly differ from the received atomic mass of yttrium. From this it appears that yttria was separated in quantity by one operation after the separation of the cerite oxides.

Application of the Cobaltamines to the Separation of the Oxides. — Many experiments were made to determine whether the sulphates of organic alkaloids would form double salts with the sulphates of the rare earths which could be made available for separations. These did not lead to satisfactory results, though double salts were formed in some cases. It then occurred to me that the sulphates and other salts of various cobaltamines, on account of their disposition to form highly crystalline compounds, might be employed with advantage. Following are the results of this investigation.

A solution of sulphate of luteocobalt precipitates completely from their cold solutions as neutral sulphates the four cerite earths now known, namely, the oxides of cerium, lanthanum, praseodymium, and neodymium. The double sulphates are beautifully crystalline, have an orange-red color, and are very slightly soluble in cold water, but practically at least insoluble in boiling water. They are soluble in acids, and sometimes crystallize from weak acid solutions. All these compounds appear to have the same constitution, which is that of the salts discovered many years since by myself, and analyzed in my laboratory by C. H. Wing.* I find, however, that the constitution of both the luteo- and roseo-salts may be much more accurately represented by the formulas:

* American Journal of Science and Art, XLIX. [2.] 363.

$$\text{I. } 2\{Co_2(NH_3)_{12}(SO_4)_3 + Ce_2(SO_4)_3\} + 3 \text{ aq.}$$
$$\text{II. } 2\{Co_2(NH_3)_{12}(SO_4)_3\} + 3\{Ce(SO_4)_2\} + 3 \text{ aq.}$$
$$\text{III. } 2\{Co_2(NH_3)_{10}(SO_4)_3 + Ce_2(SO_4)_3\} + 9 \text{ aq.}$$
$$\text{IV. } 2\{Co_2(NH_3)_{10}(SO_4)_3 + 3\{Ce(SO_4)_2\} + 9 \text{ aq.}$$

Mr. W. J. Karslake has arrived independently at the same formulas, and has calculated the percentages as required by them.

For Formula I.

		Calculated.	Found.
24 NH_3	408	16.93	16.75 (loss)
4 Co	236	9.79	9.31
4 Ce	560	23.24	24.10
12 SO_4	1152	47.80	47.77
3 H_2O	54	2.24	2.07
	2410	100.00	

For Formula II.

		Calculated.	Found.		
24 NH_3	408	17.97	17.73 (loss)		
4 Co	236	10.40	10.80	10.74	10.44
3 Ce	420	18.57	16.90	17.27	17.54
12 SO_4	1152	50.75	51.80	51.83	52.22
3 H_2O	54	2.37	2.47	2.21	2.39
	2270	100.00			

For Formula III.

		Calculated.	Found.	
20 NH_3	340	14.72	14.24 (loss)	
4 Co	236	10.22	10.39	9.60
3 Ce	420	18.18	18.18	19.36
12 SO_4	1152	49.86	49.73	49.97
9 H_2O	162	7.02	7.00	7.31
	2310	100.00		

For Formula IV.

		Calculated.	Found.
20 NH_3	340	13.88	15.13 (loss)
4 Co	236	9.64	9.90
4 Ce	560	22.85	20.99
12 SO_4	1152	47.02	47.23
9 H_2O	162	6.61	6.75
	2450	100.00	

The analyses are those of Wing. Recent determinations of the molecular masses of the cobaltamines have shown that the chlorides,

for example, of roseocobalt and luteocobalt are represented respectively by the formulas $Co(NH_3)_5Cl_3$ and $Co(NH_3)_6Cl_3$. I have kept the old formulas only to permit an easy comparison with those given by Wing, and the matter is not one of consequence in this place. It may also be remarked that, as cerium is at present the only one of the group which forms a well defined oxide higher than R_2O_3, the two formulas II. and IV. cannot be generalized by substituting the symbols of other elements for that of cerium. I have endeavored, however, to prepare such compounds by adding a solution of $Lc_2(SO_4)_3$ to one containing the sulphates of oxides other than the cerite oxides, and then adding some oxidizing agent, as for instance potassic permanganate, chlorine, or bromine. No decisive results were obtained. It is at least probable that all the earths the sulphates of which in cold solutions give only slightly soluble double sulphates with potassic and sodic sulphates will also give insoluble double sulphates with sulphate of luteocobalt. These earths are, so far as now known, Ce_2O_3, La_2O_3, Nd_2O_3, Ps_2O_3, Sm_2O_3, Sc_2O_3, while the following give soluble double sulphates: Er_2O_3, Y_2O_3, Yb_2O_3, and Tb_2O_3. The four cerite oxides cited are not the only ones which give insoluble crystalline precipitates with sulphate of luteocobalt in the cold, but I am not at present able to give more accurate information on this point. On the other hand, we meet in the case of luteocobalt sulphate with some of the relations which present themselves when the alkaline sulphates are employed. Thus sulphate of yttria is not precipitated by sulphate of luteocobalt when alone, but when mixed with the sulphates of the cerite group more or less of a double sulphate of luteocobalt and yttria is always thrown down, and the same appears to be true for the sulphates of some other earths. In such cases the mixed sulphates of earths and luteocobalt should be gently heated in a muffle until the cobaltamine is completely decomposed and the excess of sulphuric acid is expelled. The residual sulphates of cobalt and the earths should then be dissolved in cold water, filtered, and again precipitated by sulphate of luteocobalt, allowing the mixture to stand twenty-four hours. The supernatant liquid appears then to contain all but the four cerite earths. This point is, however, not yet sufficiently proved, and I reserve it for further investigation.

The solution from which the double sulphates of the cerite earths and luteocobalt have been separated by decantation or filtration usually gives a more or less abundant crystalline precipitate on boiling. The filtrate from this again gives a precipitate with ammonia. The above stated facts are precisely those which we meet with in employing

the alkaline sulphates in place of the sulphate of luteocobalt. I have also employed the sulphato-chloride of luteocobalt, $Lc_2(SO_4)_2Cl_2$, as a precipitant, and find that double salts are sometimes formed which are much more insoluble than those obtained with the sulphate, excepting only in the cases of the four cerite earths. These contain chlorine as well as sulphuric oxide, and they are sometimes at least formed when sulphate of luteocobalt is added to a solution containing the chlorides of metals of the cerium and yttrium groups. Sulphate of roseocobalt gives in general the same result as sulphate of luteocobalt, only the salts formed in this case are more soluble in both cold and hot water. Experiments with the sulphates of xanthocobalt and croceocobalt have not yet led to valuable results. Certain sulphates of the earths appear to give with sulphate of luteocobalt only hydroxides of the metals, $R(OH)_3$. In this case it seems more probable that a true double sulphate is at first formed and then decomposed, sulphuric acid being set free.

The following results may be of interest in this connection. A portion of earths from Fergusonite sent me by Dr. Shapleigh was converted into sulphates; the cerite earths had been separated by sodic sulphate, and the solution of the earths gave no further precipitate with this. A solution of sulphate of luteocobalt gave no precipitate with this solution in the cold, but on boiling a very abundant crystalline precipitate, insoluble or very slightly soluble in boiling water. The filtrate from these crystals gave only a small precipitate with ammonia, so that the luteocobalt salt must have contained almost all the earths other than the cerite earths. These are known to consist chiefly of yttria. The crystalline precipitate obtained as above by boiling, and insoluble in boiling water, dissolved completely in a large quantity of cold water. The nitrates of roseocobalt and luteocobalt give, in many cases at least, finely crystalline precipitates with the nitrates of the earths. In certain cases, white gelatinous precipitates of hydroxides are formed at the same time probably as in the case of the sulphates above cited, in consequence of the formation of double nitrates and their subsequent decomposition into free acid and hydroxide. This makes a new mode of differentiation which may prove to be of use, and to which I shall return hereafter. As an instance I may cite the case of the neutral nitrates of the gadolinite earths, from which the cerite earths have been separated by sodic sulphate. A strong solution of these nitrates gives with nitrate of roseocobalt, $Rc(NO_3)_3$, in a short time a bright orange highly crystalline and a dirty white gelatinous precipitate. Both contain earths. The same is

true for neutral nitrates from Samarskite, and from the cerite and monazite residues already mentioned. The nitrate of roseocobalt must be in excess. I have already stated that the action of the sulphates of roseocobalt and luteocobalt upon the sulphates of the earths closely resembles that of the alkaline sulphates. The advantage of using the cobaltamines consists, in part, in the fact that the double sulphates of these and the earths are highly crystalline and exceptionally well defined, and that they are in some cases at least very much less soluble than the alkaline double sulphates. The chief disadvantage is that the cobaltamines must be specially prepared for use, and that the most valuable of them — the sulphate of luteocobalt — is not easy to prepare in quantity and in a state of purity. Professor Morris Loeb has however found that sulphate of roseocobalt may be converted into sulphate of luteocobalt by heating with strong ammonia water under pressure, as for instance in sealed tubes; and as the sulphate of roseocobalt is easily prepared, this process is perhaps the best.

A solution of sulphate of luteocobalt gives a very insoluble yellow crystalline precipitate with sulphate of thoria, $Th(SO_4)_2$. It gives also slightly soluble precipitates with uranic sulphate, UO_2SO_4, and with a solution of ferric alum which has undergone dissociation by solution. This last precipitate appears to have the formula

$$Fe_2O \,.\, (SO_4)_2 + Lc_2(SO_4)_3.$$

It is my hope to be able to return to the subject in greater detail.

Relations of the Oxides to Lactic Acid. — A portion of the oxides obtained from Samarskite by Dr. Shapleigh after the cerite oxides had been separated by sodic sulphate was boiled with pure lactic acid, and gave an amethyst-red solution. On standing, this solution gave two kinds of crystals, which were very distinct and well defined. These were beautiful red flat prisms, and distinct bright yellow granular crystals. The quantity was too small to permit a more thorough examination, and I did not obtain the same result a second time with other Samarskite oxides. In one experiment, however, the solution of the oxides was deep orange, and after a time deposited crystals with a fine orange color.

The lactates of the cerite earths and of the Samarskite earths which have not been treated with potassic or sodic sulphate give beautiful white feathery crystals, which dissolve with difficulty in hot water.

Relations of Mercurous Nitrate and Mercuric Oxide to Cerite Earths. — A solution of mercurous nitrate gives in general no precipitate with neutral nitrates of the cerite earths. In one experiment, however, in

which I employed nitrates from a commercial oxalate, added a solution of mercurous nitrate, and then boiled with free mercuric oxide, the color of the oxide changed to a grayish tint. After filtering and washing, the filtrate was found to contain abundance of didymium (Nd and Ps). The precipitate after washing with boiling water was heated to redness in a platinum crucible, when a clear yellow powder remained. This dissolved in dilute nitric acid to a colorless liquid, which gave no didymium bands with the spectroscope. On adding water to the nitric acid solution a beautiful bright yellow crystalline powder was thrown down. When the oxides were treated with sulphuric acid a white crystalline mass was formed. Hot water gave with this a fine bright yellow crystalline precipitate. I did not obtain these results with any other samples of cerite oxalates. So far as I am aware no known earths exhibit the reactions with nitric and sulphuric acids above described.

Relations of the Samarskite Oxides to Acid Molybdates, and to Phospho-tungstates and Phospho-molybdates. — To determine whether any of the oxides contained in Samarskite were capable of forming complex inorganic acids, the following experiments were made with a bright yellow mixture of oxides prepared by Lawrence Smith's process with fluohydric acid. The quantity at my disposal was less than five grams, and I am not certain that the cerite oxides had been removed by sodic sulphate.

1. With 10 : 5 phospho-molybdate of ammonium. The mixed oxides dissolved very easily on boiling with solutions of the phospho-molybdate, giving a fine orange solution. The action of the solution of phospho-molybdate upon the oxides seemed to give instantly a crystalline mass, which on boiling with some excess of the phospho-molybdate dissolved. The solution gave beautiful orange-brown crystals, but after twenty-four hours the solution was clear, and had a fine rose-color. This solution gave no absorption bands with the spectroscope. With ammonic oxalate it gave a white crystalline precipitate with a clear rose-red solution. This on evaporation to dryness in a platinum vessel gave a rose-red mass, which when heated fused to a greenish mass. The white oxalate settled slowly. The orange crystalline salt dissolved almost completely in boiling water, but some yellow crystalline matter remained. On standing, the solution deposited crystals of a yellow salt.

2. With 14 : 6 molybdate of ammonium. A solution of 14 : 6 molybdate of ammonium (commonly written $7\,MoO_3 . 3\,(MH_4)_2O$) also readily dissolved the mixed oxides and gave a deep orange solution.

On standing twenty-four hours this gave bright yellow and afterwards very beautiful glittering orange-red crystals. The two kinds of crystals redissolved gave with mercurous nitrate a pale yellow flocky precipitate which on boiling and standing became bright yellow and highly crystalline. The least soluble crystals were also redissolved separately, and after twenty-four hours crystallized in beautiful prehnitic groups. The orange mother liquor from these crystals gave the reaction with mercurous nitrate mentioned above. It seems probable from the above that 14 : 6 molybdate of ammonium gives at least two distinct salts.

3. With 24 : 2 sodic phospho-tungstate. A solution of this salt also dissolved the Samarskite oxides very readily on boiling, giving a fine orange-red solution which soon deposited an abundance of yellow needles. These dissolved readily in hot water to a yellow solution with an orange tint. Yellow needles quickly formed in abundance. After an hour the still slightly warm mother liquor was poured off and allowed to stand. Two kinds of crystals separated, — very distinct rather large granular orange crystals in much the larger quantity, and very small granular yellow crystals differing much from the last in appearance. The two kinds of crystals were dissolved together in hot water, and after a time gave flocky masses of yellow crystals.

I did not succeed in obtaining the same results with other preparations of Samarskite oxides. This will not surprise those who have worked with the rare earths, and who have noticed the difference in the reactions which depends upon difference in the proportions of the mixed oxides. It has, I believe, escaped notice that the same occurs with mixtures of the different metals of the platinum group as long since shown by Claus.

The compounds with molybdic oxide and with phospho-molybdic and phospho-tungstic acids may prove to be only salts of the earths, and not of complex acids. They appear to deserve further attention as means of separation. As the minerals belonging to the same group with gadolinite resemble each other very closely in their physical characters, it is possible that the yellow oxides above mentioned were not prepared from Samarskite, but from some other mineral.

Analyses 1 to 46 and from 69 to 122 inclusive were made by Mr. Edward L. Smith; from 47 to 68 inclusive by Mr. Wm. J. Karslake. My grateful acknowledgments are due to both.

NEWPORT, R. I., July 30, 1893.

XIX.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

TURMEROL.

By C. Loring Jackson and W. H. Warren.

Presented October 12, 1892.

Some years ago one of us, in conjunction with A. E. Menke, described a compound obtained from the oily extract of turmeric, to which the name of turmerol was given.* The present paper contains some additional work on this substance, which we are obliged to publish in an unfinished state because the departure of one of us from Cambridge prevents us from continuing the work together.

The turmerol at the time of its discovery was purified by distillation *in vacuo*, but the method used was a very imperfect one, because at that time no description of the best methods now in use had come to our notice, if indeed they had been described at all. Accordingly when we returned to the subject we felt it was necessary to revise this part of the work, and for this purpose applied to the turmerol the excellent method of fractional distillation *in vacuo* contrived by Anschütz, and soon found that the preparation studied by one of us and Menke was impure, and therefore that the formula of turmerol needed correction. Our analyses of a sample carefully purified and proved to be homogeneous by the analyses of different fractions led to the formula $C_{13}H_{18}O$ or $C_{14}H_{20}O$. We have been unable to determine which of these is correct, because the difference between them is only 0.25 per cent for the carbon. This new formula agrees much better with the formulas of the oxidation products already obtained than that assigned to turmerol in the first paper on this subject.

The oxidation of turmerol with dilute nitric acid converted it into paratoluylic acid, which was identified by its melting point, 178°, the analyses of its calcium salt and anilid, and its conversion into tereph-

* These Proceedings, XVIII. 8.

thalic acid by further oxidation. This observation proves that turmerol contains a benzol ring with a methyl group attached to it, and a long side-chain of six (or seven) atoms of carbon in the para position to the methyl. In regard to the nature of the long side-chain we cannot speak with certainty, but it has been proved that one of the atoms of carbon in it is unsymmetrical, because turmerol shows circular polarization, and that the atom of oxygen is attracted to this side-chain. The earlier work of Menke and one of us further seems to indicate that turmerol is an alcohol,* and that it is oxidized by cold potassic permanganate with formation of acetic acid, carbonic dioxide, and two acids, $C_{11}H_{14}O_2$ (turmeric acid), and $C_{10}H_{12}O_4$? (apoturmeric acid).† We feel, however, that this earlier work needs revision before these points can be considered definitely settled, as the experiments on the alcoholic nature of turmerol are susceptible of an interpretation different from that given to them in the paper in which they were described, and the formula of apoturmeric acid is very doubtful. This revision will be undertaken in this Laboratory, it is hoped, during the coming year.

Although it would be easy to assign a provisional formula to turmerol in accordance with the facts already observed, we have thought it wiser to postpone doing this until further investigation has given us a more secure foundation for such a formula.

Purification and Analysis of Turmerol.

The crude turmeric oil extracted from ground Bengal turmeric with ligroine, as described in an earlier paper,‡ was heated to 150° under ordinary pressure for some time to remove as much as possible of the ligroine, and then distilled under a pressure of 11–12 mm. according to the method of Anschütz, carrying the temperature to 200°. This separated it into a small lower fraction containing ligroine, a larger one consisting principally of turmerol, and a viscous retort residue which formed about one half of the original oil. The large middle portion was repeatedly fractioned at a pressure of 11–12 mm., which divided it into a small lower fraction containing ligroine, an insignificant retort residue, and the principal amount boiling from 158° to 163° under 11–12 mm. pressure. To test the purity of this substance it was distilled under the same diminished pressure once more, collecting the product in three fractions, the first and last very small in

* These Proceedings, XVIII. 11.

† These Proceedings, XIX. 215.

‡ These Proceedings, XVII. 112.

quantity, the middle one containing most of the substance, and these three fractions were then analyzed with the following results: —

I. 0.3701 gr. of the lowest fraction gave on combustion 1.1215 gr. of carbonic dioxide and 0.3274 gr. of water.

II. 0.4331 gr. of the middle fraction gave on combustion 1.3071 gr. of carbonic dioxide and 0.3802 gr. of water.

III. 0.4795 gr. of the highest fraction gave on combustion 1.4469 gr. of carbonic dioxide and 0.4153 gr. of water.

		Found.	
	I.	II.	III.
Carbon	82.64	82.28	82.30
Hydrogen	9.83	9.75	9.62

This experiment showed that the substance was not perfectly pure, since the lowest fraction contained more carbon than either of those which came over at higher temperatures. Accordingly the distillation at a pressure of 11–12 mm. was repeated, removing each time only a very small fraction which came over first, until this small lower fraction gave on analysis the same result as the portion left in the boiling flask. This occurred after the third distillation, when the following results were obtained: —

IV. 0.3408 gr. of the small lowest fraction gave on combustion 1.0265 gr. of carbonic dioxide and 0.2963 gr. of water.

V. 0.3658 gr. of the principal fraction gave on combustion 1.1041 gr. of carbonic dioxide and 0.3175 gr. of water.

	Found.	
	IV.	V.
Carbon	82.13	82.28
Hydrogen	9.66	9.65

To these analyses we add another of an entirely different sample of turmerol.

VI. 0.5045 gr. of the substance gave on combustion 1.5246 gr. of carbonic dioxide and 0.4375 gr. of water.

The percentages of carbon and hydrogen obtained from the analyses of pure turmerol are collected in the following table: —

	II.	III.	IV.	V.	VI.
Carbon	82.28	82.30	82.13	82.28	82.39
Hydrogen	9.75	9.62	9.66	9.65	9.64

These results agree nearly with those calculated for the following formulas:—

	Calculated for	
	$C_{13}H_{18}O$.	$C_{14}H_{20}O$.
Carbon	82.10	82.35
Hydrogen	9.47	9.80

Of these we prefer the first, as this brings the calculated percentage of hydrogen below those found. On the other hand the percentages of carbon found are all a little too high for this formula, which may perhaps be due to the presence of a trace of ligroine. It is evident that it is impossible to decide with certainty from these analyses which of these formulas is the correct one.

Properties of Turmerol. — The turmerol, after the purification described above, forms a yellowish oil, with a peculiar rather agreeable odor. It is decomposed partially by distillation at ordinary pressure, but under a pressure of 11–12 mm. it distils unchanged between 158° and 163°. Its specific gravity at 24°, referred to water at 4°, is 0.9561. Turmerol acts upon polarized light, turning the ray toward the right, with the following specific rotation for sodium light:

$$[\alpha]_D = 24^\circ.58.$$

It mixes easily with the common organic solvents, but is insoluble in water.

Oxidation of Turmerol with Nitric Acid.

In a previous paper* one of us with A. E. Menke showed that turmerol, when oxidized in the cold with potassic permanganate, gave in addition to carbonic dioxide and acetic acid two new acids, to which the names turmeric acid and apoturmeric acid, and the formulas $C_{11}H_{14}O_2$ and $C_{10}H_{12}O_4$? were assigned. As in this work the characterization of the apoturmeric acid was far from satisfactory owing to the very small yields and the unmanageable nature of these acids and their salts, and as we hoped by further study of these substances to throw light on the constitution of turmerol, we took up this part of the subject again. Since the preparation and purification according to the methods used in the earlier work were tedious in the highest degree, we tried the action of dilute nitric acid on turmerol in the hope that this might lead us more quickly to the desired result. This did not prove to be the case, but the product obtained was quite as important as the two acids we had hoped to get.

* These Proceedings, XIX. 215.

We proceeded as follows. A convenient quantity of turmerol was boiled with nitric acid (one part of acid of 1.38 specific gravity diluted with two parts of water) under a reverse condenser for some time. The yellow solution was filtered hot, and on cooling deposited a white crystalline substance which sublimed very easily at a little over 170°. It was purified by sublimation, followed by warming with tin and hydrochloric acid to remove any nitro compound which might have been formed; after this it was crystallized from boiling water until it showed a constant melting point, which stood at 178°. This at once suggested that the substance was the paratoluylic acid $CH_3C_6H_4COOH$, which melts according to Beilstein and Yssel * at 176° to 177°, according to Fischli † at 180°. To confirm this inference we analyzed the calcium salt with the following results: —

I. 0.1106 gr. of the air-dried salt lost 0.0165 gr. when dried at 140°.
II. 0.1212 gr. of the air-dried salt lost 0.0176 gr. when dried at 140°.

	Calculated for $(C_8H_7O_2)_2Ca \cdot 3H_2O$.	Found. I.	II.
Water	14.83	14.92	14.52

0.2848 gr. of the calcium salt dried at 140° gave 0.1246 gr. of calcic sulphate.

	Calculated for $(C_8H_7O_2)_2Ca$.	Found.
Calcium	12.90	12.86

The amount of water found (three molecules) corresponds to that obtained by Beilstein and Yssel * in the calcium salt of paratoluylic acid. We also converted the acid into its anilid by treating it successively with phosphoric pentachloride and aniline. This after repeated crystallization from dilute alcohol melted constant at 143°, and gave the following result on analysis: —

0.1122 gr. of the substance gave 7 c.c. of nitrogen at a temperature of 29° and a pressure of 753.7 mm.

	Calculated for $C_8H_7ONHC_6H_5$	Found.
Nitrogen	6.63	6.75

* Ann. Chem., CXXXVII. 302.
† Ber. d. ch. G., XII. 615.

Here again the analysis gave the desired result, but our anilid melted at 143°, whereas according to Fischli * the anilid of paratoluylic acid melts at 139°, according to Brückner † at 140–141°; we felt, therefore, that further proof of the para position of the side-chains in our acid was necessary, and this we obtained by the oxidation of the acid with potassic dichromate, according to the directions given by Beilstein and Yssel. For this purpose 0.5 gr. of our acid was boiled in a flask with a return condenser with four parts of potassic dichromate, and an excess of sulphuric acid diluted with twice its volume of water, until there was a copious white precipitate; this was then filtered out, boiled three times with water, and the residue converted into its dimethylester, which melted at 140–141°, thus proving that the product was terephthalic acid, and that our acid was the paratoluylic acid. We may add that a certain amount of terephthalic acid was always obtained with the paratoluylic acid when we oxidized turmerol with dilute nitric acid.

Some unsuccessful attempts to make derivatives of the turmerylchloride, which was described in a previous paper,‡ may be mentioned here. The chloride was made by heating phosphorous trichloride with turmerol for three hours. The product was purified by washing its ethereal solution with dilute sodic hydrate and water, drying with calcic chloride, and distilling off the ether. It formed a dark oil, with a smell very different from that of turmerol, but, as it decomposed even when distilled at a pressure of 12 mm., no attempt was made to analyze it again. In the hope of obtaining an aldehyd or ketone from it, 10 gr. of the chloride were boiled with an aqueous solution of plumbic nitrate. Some plumbic chloride was formed, but the quantity of chlorine removed was only 0.2363 gr., whereas the amount calculated for the complete reaction was 1.868 gr.; we obtained therefore only 12.65 per cent of the calculated amount, and, as the reaction was so incomplete, it is not surprising that we were unable to isolate the organic product. We also tried the action of potassic phthalimide on the turmerylchloride in the hope of getting a turmerylamine, but found there was no action at 100°, little or none at 150°. From these results it is evident that turmerylchloride is not a very reactive substance.

* Ber. d. ch. G., XII. 615.

† Ann. Chem., CCV. 132.

‡ These Proceedings, XVIII. 11.

PROCEEDINGS.

Eight hundred and fifty-first Meeting.

May 24, 1892. — ANNUAL MEETING.

The PRESIDENT in the chair.

A quorum was not present and it was

Voted, To meet on adjournment on Wednesday the 15th of June.

The Report of the Council was read.

The Treasurer and the Librarian presented their annual reports.

The following papers were presented by title: —

Note on Orthogonal Matrices. By Henry Taber.

On the least Number of Vibrations necessary to determine Pitch. By Charles R. Cross and Margaret E. Maltby.

On some Experiments with the Phonograph, relating to the Vowel Theory of Helmholtz. By Charles R. Cross and George E. Wendell.

An Investigation of the Excursion of the Diaphragm of a Telephone Receiver. By Charles R. Cross and Arthur M. Mansfield.

New Phænogams collected in New Mexico by C. G. Pringle in 1890 and 1891. By Benjamin L. Robinson.

Eight hundred and fifty-second Meeting.

June 15, 1892. — ADJOURNED STATED MEETING.

The PRESIDENT in the chair.

The Reports of the Council, the Treasurer, and the Librarian, read at the last meeting, were accepted.

On the motion of the Treasurer it was

Voted, To make the following appropriations from the income of the general fund: —

For general expenses	$2,200
For publications	2,100
For the library	1,500
For the expenses of meetings . . .	200

The following gentlemen were elected members of the Academy: —

Solon Irving Bailey, of Cambridge, to be a Resident Fellow in Class I., Section 2.

George Dunning Moore, of Worcester, to be a Resident Fellow in Class I., Section 3.

Charles Edward Faxon, of Boston, to be a Resident Fellow in Class II., Section 2.

Benjamin Lincoln Robinson, of Somerville, to be a Resident Fellow in Class II., Section 2.

Arthur Bliss Seymour, of Cambridge, to be a Resident Fellow in Class II., Section 2.

Roland Thaxter, of Cambridge, to be a Resident Fellow in Class II., Section 2.

John Elbridge Hudson, of Boston, to be a Resident Fellow in Class III., Section 1.

Charles Pickering Bowditch, of Boston, to be a Resident Fellow in Class III., Section 2.

Edward Robinson, of Boston, to be a Resident Fellow in Class III., Section 2.

Edmund Hatch Bennett, of Boston, to be a Resident Fellow in Class III., Section 3.

Mellen Chamberlain, of Chelsea, to be a Resident Fellow in Class III., Section 3.

Andrew McFarland Davis, of Cambridge, to be a Resident Fellow in Class III., Section 3.

Ephraim Emerton, of Cambridge, to be a Resident Fellow in Class III., Section 3.

Silas Marcus Macvane, of Cambridge, to be a Resident Fellow in Class III., Section 3.

Charles Card Smith, of Boston, to be a Resident Fellow in Class III., Section 3.

Francis Bartlett, of Boston, to be a Resident Fellow in Class III., Section 4.

John Bartlett, of Cambridge, to be a Resident Fellow in Class III., Section 4.

Thomas Wentworth Higginson, of Cambridge, to be a Resident Fellow in Class III., Section 4.

Percival Lowell, of Brookline, to be a Resident Fellow in Class III., Section 4.

Fabian Franklin, of Baltimore, to be an Associate Fellow in Class I., Section 1, in place of the late William Ferrel.

Emory McClintock, of New York, to be an Associate Fellow in Class I., Section 1, in place of the late Thomas Hill.

Edward Emerson Barnard, of San José, to be an Associate Fellow in Class I., Section 2, in place of the late Julius E. Hilgard.

James Edward Keeler, of Allegany, to be an Associate Fellow in Class I., Section 2, in place of the late Christian H. F. Peters.

Edward Williams Morley, of Cleveland, to be an Associate Fellow in Class I., Section 3, in place of the late John LeConte.

Cyrus Ballou Comstock, of Washington, to be an Associate Fellow in Class I., Section 4, in place of the late George W. Cullum.

Alfred Richard Cecil Selwyn, of Ottawa, to be an Associate Fellow in Class II., Section 1, in place of the late John C. Fremont.

William Trelease, of St. Louis, to be an Associate Fellow in Class II., Section 2, in place of the late Leo Lesquereux.

George Vasey, of Washington, to be an Associate Fellow in Class II., Section 2.

William Keith Brooks, of Baltimore, to be an Associate Fellow in Class II., Section 3, in place of the late Joseph Leidy.

Thomas Ruggles Pynchon, of Hartford, to be an Associate Fellow in Class III., Section 1, in place of the late Noah Porter.

David Ames Wells, of Norwich, Connecticut, to be an Associate Fellow in Class III., Section 3.

Johan August Hugo Gyldén, of Stockholm, to be a Foreign Honorary Member in Class I., Section 1, in place of the late John C. Adams.

William Huggins, of London, to be a Foreign Honorary Member in Class I., Section 2, in place of the late Sir George B. Airy.

Hermann Carl Vogel, of Potsdam, to be a Foreign Honorary Member in Class I., Section 2, in place of the late Eduard Schönfeld.

Victor Meyer, of Heidelberg, to be a Foreign Honorary Member in Class I., Section 3, in place of the late Wilhelm E. Weber.

Henry Clifton Sorby, of Sheffield, to be a Foreign Honorary Member in Class II., Section 1, in place of the late Sir Andrew C. Ramsay.

Baron Ferdinand von Mueller, of Melbourne, to be a Foreign Honorary Member in Class II., Section 2, in place of the late Carl J. Maximowicz.

Eduard Strasburger, of Bonn, to be a Foreign Honorary Member in Class II., Section 2, in place of the late Carl W. von Naegeli.

The annual election resulted in the choice of the following officers: —

JOSIAH P. COOKE, *President.*
AUGUSTUS LOWELL, *Vice-President.*
CHARLES L. JACKSON, *Corresponding Secretary.*
WILLIAM WATSON, *Recording Secretary.*
ELIOT C. CLARKE, *Treasurer.*
HENRY W. HAYNES, *Librarian.*

Councillors.

WILLIAM E. STORY,
CHARLES R. CROSS, } of Class I.
WILLIAM R. LIVERMORE,

DAVID W. CHEEVER,
HENRY P. WALCOTT, } of Class II.
GEORGE L. GOODALE,

LUCIEN CARR,
ANDREW P. PEABODY, } of Class III.
BARRETT WENDELL,

Rumford Committee.

N O. PEIRCE,
C. PICKERING,
R. CROSS,

nance.

Standing Com-

G. FARLOW,

ROPES.

The following papers were presented: —

On the Matrical Equation $\Omega\,\phi = \phi\,\Omega'$. By Henry Taber.

On the so called Hall Effect in several Metals at widely varying Temperatures. By A. L. Clough and E. H. Hall.

On the Thermal Conductivity of Cast Iron and of Cast Nickel. By E. H. Hall.

A letter was read from the General Committee of the World's Congress Auxiliary on Mathematics and Astronomy, calling the attention of the Academy to its printed preliminary address.

Eight hundred and fifty-third Meeting.

October 12, 1892. — STATED MEETING.

The PRESIDENT in the chair.

In the absence of the Recording Secretary, Major W. R. Livermore was elected Secretary *pro tempore.*

The Corresponding Secretary read letters from Messrs. J. Bartlett, Bennett, Bowditch, Chamberlain, Higginson, Hudson, Lowell, Moore, Robinson, and Smith, accepting Fellowship; from Messrs. Barnard, Comstock, Keeler, McClintock, Pynchon, Selwyn, Trelease, and Vasey, acknowledging election as Associate Fellows; and from Messrs Gyldén, Huggins, Sorby, Strasburger, and Vogel, acknowledging election as Foreign Honorary Members.

The President announced the decease of James Bicheno Francis and John Greenleaf Whittier, Fellows; and of Sir William Bowman and Lord Tennyson, Foreign Honorary Members.

On motion, it was

Voted, To meet on adjournment on the second Wednesday in November.

The following papers were presented: —

On Turmerol. By Charles L. Jackson.

On Alaska. By Josiah P. Cooke.

Eight hundred and fifty-fourth Meeting.

November 9, 1892. — ADJOURNED STATED MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary announced the death of Professor Giovanni Flechia, Vice-President of the Royal Academy of Science at Turin; also, that of Commander Antonio Todardo, Director of the Royal Botanic Garden at Palermo. He read a letter inviting members of the Academy to attend the seventy-fifth anniversary of the Natural History Society of Osterland, at Altenburg, and one from Baron von Mueller, acknowledging his election as Foreign Honorary Member.

The Recording Secretary proposed an amendment of the first section of Chapter VIII. of the Statutes, and, on his motion, it was

Voted, That this recommendation be referred to a committee, with instructions to report at the next stated meeting.

The President appointed the Recording Secretary, Dr. Folsom, and Major Livermore members of this committee.

The following papers were presented: —

Characteristics of the Mycological Flora of North America. By William G. Farlow.

Mechanical Models of Electro-magnetic Phenomena. By Amos E. Dolbear.

The following papers were presented by title: —

On certain Products of the Dry Distillation of Wood: Methylfurfurol and Methylpyromucic Acid. By Henry B. Hill and Walter L. Jennings.

On Certain Derivatives of Pyromucamide. By Charles E. Saunders.

On Triahilidodinitrobenzol and some related Compounds. By C. Loring Jackson and H. N. Herman.

On the Tropical Faunal Element of our Southern Nymphalinæ systematically treated. By Samuel H. Scudder.

Eight hundred and fifty-fifth Meeting.

January 11, 1893. — Stated Meeting.

The President in the chair.

The committee appointed to consider the proposed amendment of the Statutes reported favorably and it was accordingly

Voted, To amend Section 1 of Chapter VIII. of the Statutes by substituting the word "second" for the words "day next preceding the last." The section thus amended reads as follows: —

"1. There shall be annually four stated meetings of the Academy; namely, on the second Wednesday in May (the Annnal Meeting), on the second Wednesday in October, on the second Wednesday in January, and on the second Wednesday in March; to be held in the Hall of the Academy, in Boston. At these meetings only, or at meetings adjourned from these and regularly notified, shall appropriations of money be made, or alterations of the statutes or standing votes of the Academy be effected."

The President addressed the Academy as follows: —

I have to report to the Academy the death of three of our members.

Professor Eben Norton Horsford died of heart disease at his residence in Cambridge on Sunday, the first day of the new year. He was born at Moscow, Livingston County, New York, on July 27, 1818, and was therefore in the seventy-fifth year of his age, As a boy, he enjoyed the advantages of good school education, and graduated from the Rensselaer Institute in 1837. Subsequently he taught for four years in the Albany Female Academy, and lectured on chemistry in Newark College, Delaware. Thus acquiring a strong interest in chemical science, he sought eagerly the remarkable advantages then offered for the study of this subject at Liebig's famous laboratory at Giessen, in Germany. Here, under the direction of Liebig, he carried out successfully and published an important investigation on glycocoll, and during two years was associated with such men as Hofmann, Wurtz, Williamson, and Frankland, who afterwards became chiefs among the makers of our modern science. With these earnest fellow students Mr. Horsford formed intimate friendships, and they ever entertained for him a warm regard.

Returning home in 1846 with the warmest recommendations from his great teacher, Mr. Horsford was at once called to direct the chemical department of the Scientific School then just established at Harvard College. The funds of the Rumford Foundation were, perhaps not wholly justifiably, diverted to the support of this department, and Mr. Horsford was appointed Rumford Professor. He entered on his duties with great zeal, and inspired such confidence in Mr. Abbott Lawrence as to lead that noble benefactor to build a large chemical laboratory, on the most approved German plan, under the supervision of the enthusiastic teacher, and the original laboratory of the Lawrence Scientific School was far in advance of any similar establishment in the United States at the time.

The outlook for the new laboratory at the beginning was most auspicious, and the young director had an earnest zeal for purely scientific investigation. But, unfortunately, the ways and means had not been adequately provided. Not only there was not sufficient income to defray the expenses of so large an establishment, but it was impossible to provide for the necessities of a growing family on the wretched stipend of $1,500 a year. These necessities forced Professor Horsford, as they have many another man, to endeavor to supplement his resources by commercial work, and, however much we may deem such work incompatible with the highest interests of a learned institution, our whole sympathy is with the struggling teacher who is forced by such circumstances to loose his hold on higher ideals. As the commercial work widened, Professor Horsford saw that it was incompatible with the full discharge of the duties of his office, and in 1863 he resigned his professorship, in honorable distinction from the too frequent practice of using a college position as a basis for commercial work.

It is with great pleasure that we follow Professor Horsford into commercial life, and witness the reward that came to intelligence, perseverance, and industry. If he suffered the trial of renouncing the ideals of youth, he won the great rewards which come from large liberality and active benevolence wisely ordered; and his name will long be cherished in loving remembrance by many hearts. Professor Horsford was elected a Fellow of this Academy on May 25, 1847.

John Strong Newberry was born in Windsor on December 22, 1822. At an early age his parents removed to Ohio, and he was educated at the Western Reserve College and the Cleveland Medical School. After supplementing his professional education in Europe, he settled as a physician in Cleveland; but in 1855 his interest in

geology led him to join, nominally as surgeon, but in reality as geologist, the exploring party sent out under the command of Lieutenant Robert S. Williamson to examine the country between San Francisco and the Columbia River, and the result of his work appears in the sixth volume of the Pacific Railroad Surveys, published by the government in 1857. He next joined the expedition under Lieutenant Ives to explore the Colorado, and spent nearly a year at the mouth of the Grand Cañon in studying the geology and natural history of that territory. His observations formed the most interesting material that was gathered by the expedition, and more than one half of the Report upon the Colorado River, published by the government in 1861, was written by him; and it was doubtless the interest aroused by this account that led Major Powell, ten years later, to make his famous explorations of the great cañons of the Colorado.

During the war of the Rebellion, Professor Newberry was one of the most efficient directors of the United States Sanitary Commission. After the war was over, he accepted the Chair of Geology and Palæontology at Columbia College, and discharged the duties until December, 1890, when a sudden stroke of paralysis incapacitated him for further work. From this attack he partially recovered, but it was the beginning of the end. Professor Newberry was elected an Associate Fellow of the Academy on March 9, 1887.

The death of Sir Richard Owen removes from the ranks of English men of science one who has been a prominent figure for over sixty years. Born in 1804, his life has covered almost the whole of a century remarkable for its scientific achievements. Already, in 1851, when the writer first met him, he had published his famous catalogue of the Hunterian Museum, and done the larger part of the work which has rendered him so illustrious as a physiologist and anatomist. Although at times regarded as overbearing by his immediate associates, he was all kindness to a stranger, and I shall never forget our pleasant intercourse. He held in very high esteem our own distinguished comparative anatomist, the late Jeffries Wyman, by whom I was introduced to his notice. The last few years he has lived in retirement at Sheen Lodge, Richmond Park, granted him by the royal family, by whom he was highly esteemed, and his death at nearly ninety is simply the natural close of a completed career. Owen was elected a Foreign Honorary Member of this Academy on November 14, 1855, and is the oldest name on our honorary list with one exception, — Pascual de Gayangos, elected in 1842.

The Corresponding Secretary read a letter from the Hermite Committee, announcing their intention to give a medal to M. Hermite on his seventieth birthday, and inviting subscriptions; also, a letter from the American Philosophical Society, inviting the Academy to send a delegate to the celebration of its one hundred and fiftieth anniversary. This invitation was accepted, and the President was requested to appoint a delegate.

Messrs. Francis H. Storer, Charles L. Jackson, Thomas M. Drown, Arthur M. Comey, and Leonard P. Kinnicutt were appointed a committee to consider and report upon methods for the management of the C. M. Warren trust for the encouragement of chemical research.

Upon the recommendation of the Rumford Committee, it was

Voted, That an appropriation of two hundred and fifty dollars ($250) be made to Professor Daniel Shea, of Illinois State University, for an investigation upon the effect of a magnetic field on light.

Voted, That an appropriation of two hundred dollars ($200) be made to Professor B. O. Peirce for an investigation on the conduction of heat.

The following papers were read: —

Notice of the late James B. Francis. By Hiram F. Mills.

Note on an Approximate Trigonometric Expression for the Fluctuations in Temperature of the Steam in an Engine Cylinder. By Edwin H. Hall.

The following papers were presented by title: —

Contributions from the Herbarium of Harvard University: 1. New and little known Plants collected on Mount Orizaba in the Summer of 1891. By Henry E. Seaton. 2. Additions to the Phænogamic Flora of Mexico, discovered by C. G. Pringle in 1891 and 1892. By B. L. Robinson and H. E. Seaton.

On the Excursion of the Diaphragm of a Telephone Receiver. By Charles R. Cross and Henry M. Phillips.

A Revision of the Atomic Weight of Barium. First Paper: The Analysis of Baric Bromide. By Theodore Wm. Richards.

On the Development of the Spermogonium of Cæoma nitens (Schw.). By H. M. Richards.

Certain Microscopic Observations in regard to the Caoutchoucs. By H. F. Lueders.

Microchemical Behavior of the Organized Proteids in the Seeds of Gossypium, with a New Test for Associated Oils. By H. F. Lueders.

Microscopic Characters of the Fossil Resin of Agathis Australis. By G. L. Goodale.

Eight hundred and fifty-sixth Meeting.

February 8, 1893.

The PRESIDENT in the chair.

The Corresponding Secretary read the following letters: from the Royal Academy of Sciences of Turin, announcing the terms of competition for the ninth Bressa Prize; from the Imperial Russian Mineralogical Society of St. Petersburg, announcing the death of its Honorary Director, Nicholas Koscharow, and of its Honorary Member, Axel Gadoline; also, from a committee at Altenburg, inviting subscriptions to the Brehm-Schlegel monument.

The President announced the death of the Rt. Rev. Phillips Brooks, D. D., a Resident Fellow, in the following words: —

That great and noble man whose recent death has caused such a profound sensation in this community was a Resident Fellow of our Academy in the section of Philosophy and Jurisprudence. Except on a few special occasions, he never attended our meetings; and his activities were in fields very different from those we habitually cultivate. But he welcomed, with as great pleasure as any of us, all advances of knowledge, and has shown his sympathy by giving to our Academy the support of his name and influence since 1878.

In his wonderful intuitive power and his great breadth of view, Phillips Brooks always seemed to me to resemble our late Foreign Honorary Member, the illustrious English poet, who died only a few weeks before him. Tennyson was conspicuously the poet of modern science. Although a son of the Church, he was the first of the poets

to appreciate the philosophic doubts which the discoveries of modern science had opened; but though he pointed out the larger view which these unfold, it

"Is given in outline and no more."

Brooks, like Tennyson, preached the Gospel of reconciliation, but his spiritual insight was so clear that all men could see the light.

"And what I am beheld again
What is, and no man understands;
And out of darkness came the hands
That reach thro' nature moulding men."

The following papers were read: —

Obituary Notice of Sir William Bowman, Bart. By Henry W. Williams.

An Account of the Spectral Well in Virginia. By Amos E. Dolbear.

On the Preparation of Nickel Tetracarbonyl. By Francis G. Benedict.

Further Evidence of the Definiteness of the Law of Constant Proportions in Chemistry. By Henry F. Brown.

The following paper was presented by title: —

Studies on the Transformations of Moths of the Family of Saturniidæ. By Alpheus S. Packard.

Eight hundred and fifty-seventh Meeting.

March 8, 1893. — Stated Meeting.

The President in the chair.

The President announced the death of John Montgomery Batchelder and Henry Wheatland, Resident Fellows, and of Frederick Augustus Genth and William Petit Trowbridge, Associate Fellows.

Dr. Henry W. Williams gave an informal talk on the revelations obtained by means of the ophthalmoscope, illustrated by models and diagrams.

A quorum for business was not present, and it was

Voted, To meet on adjournment on the 12th of April.

Eight hundred and fifty-eighth Meeting.

April 12, 1893. — ADJOURNED STATED MEETING.

The PRESIDENT in the chair.

The President announced the death since the last meeting of Andrew Preston Peabody, and George Cheyne Shattuck, Resident Fellows; William Holmes Chambers Bartlett, and George Vasey, Associate Fellows; and of Alphonse Louis Pierre Pyramus de Candolle, Foreign Honorary Member.

The following gentlemen were elected members of the Academy: —

Samuel Cabot, of Brookline, to be a Resident Fellow in Class I, Section 3.

Henry Helm Clayton, of Milton, to be a Resident Fellow in Class II., Section 1.

John Elliott Pillsbury, of Boston, to be a Resident Fellow in Class II., Section 1.

John Henry Wright, of Cambridge, to be a Resident Fellow in Class III., Section 2.

The following report was presented: —

The provisional committee appointed to consider methods of managing the "Cyrus Moors Warren Trust for the encouragement of Chemical Research" respectfully recommend to the Academy that a standing committee be appointed to be known as the

C. M. WARREN COMMITTEE,

which shall consist of seven (7) members to be chosen by ballot at the Annual Meeting of the Academy, vacancies to be filled at any stated meeting of the Academy after due notice has been given at a previous meeting of the proposed election.

We recommend that the C. M. Warren Committee should be directed by the Academy: —

I. To invite applications for pecuniary assistance from any persons wishing to engage in research in any department of chemistry; that the Committee should consider these appli-

cations carefully and recommend to the Academy for its favorable action such applications as seem to be practicable and to be worthy of aid. We urge that preference should be given to work upon petroleum products and hydrocarbons, because of Mr. Warren's special interest in the study of these substances.

II. We recommend that the Committee should be authorized to suggest subjects that need to be investigated, and be directed to employ a chemist, or several chemists, at its discretion, to work out definite stated problems, under the supervision of the Committee. Preference should naturally be given to actual laboratory work, but research in the literature of chemistry, and other forms of literary labor, should not be excluded when in the opinion of the Committee the elucidation of a problem might be promoted by these means.

III. The Committee should be empowered on occasion to purchase materials and apparatus — including printed or written memoirs — which may be needed for the investigations which may be recommended, and should be permitted to employ assistants when necessary.

IV. We are of opinion that no medal or other form of prize should be given or offered by the Academy in connection with the Warren Trust.

All of which is respectfully submitted by

F. H. Storer.
C. L. Jackson.
A. M. Comey.
L. P. Kinnicutt.

The report was accepted and adopted by the Academy.

The following papers were presented by title: —

Contributions from the Gray Herbarium of Harvard University: The North American Sileneæ and Polycarpeæ. By B. L. Robinson.

The "Hall Effect" at widely varying Temperatures in several Metals. By A. L. Clough and E. H. Hall.

On the Representation of Real Orthogonal Transformations. By Henry Taber.

On Hemiacetals from Substituted Chloranils. By C. Loring Jackson and H. S. Grindley.

On Substituted Crotonolactones and Mucobromic Acid. By H. B. Hill and R. W. Cornelison.

Notice was given by the Recording Secretary of a proposed change in the second section of Chapter VIII. of the statutes. This recommendation was referred to a committee, consisting of the Recording Secretary, the Corresponding Secretary, and the Librarian.

AMERICAN ACADEMY OF ARTS AND SCIENCES.

Report of the Council. — Presented May 10, 1893.

BIOGRAPHICAL NOTICES.

John Montgomery Batchelder . . .	By John Trowbridge.
Henry Ingersoll Bowditch	Charles F. Folsom.
Phillips Brooks	William R. Huntington.
James Bicheno Francis	William E. Worthen.
Eben Norton Horsford	Charles L. Jackson.
William Raymond Lee	John C. Ropes.
Lewis Mills Norton	Thomas M. Drown.
Andrew Preston Peabody	Edward E. Hale.
George Cheyne Shattuck	Samuel Eliot.
John Greenleaf Whittier	Barrett Wendell.
William Ferrel	William M. Davis.
Frederick Augustus Genth	Wolcott Gibbs.
John Strong Newberry	Raphael Pumpelly.
William Petit Trowbridge	Gaetano Lanza.
George Vasey	Benjamin L. Robinson.
William Bowman	Henry W. Williams.
Alphonse Louis Pierre Pyramus De Candolle	William G. Farlow.
August Wilhelm von Hofmann . .	Charles L. Jackson.
Richard Owen	Thomas Dwight.
Alfred Tennyson	Edward J. Lowell.

Notices of Lowell, Wheatland, Bartlett, and Caligny are necessarily deferred to the next volume; while those of Bowditch, Lee, Ferrel, and Hofmann, deferred from last year, are given below.

REPORT OF THE COUNCIL.

SINCE the Annual Meeting of the 24th of May, 1892, the Academy has lost by death eighteen members; — nine Fellows, John Montgomery Batchelder, Phillips Brooks, James Bicheno Francis, Eben Norton Horsford, Lewis Mills Norton, Andrew Preston Peabody, George Cheyne Shattuck, Henry Wheatland, and John Greenleaf Whittier; five Associate Fellows, William Holmes Chambers Bartlett, Frederick Augustus Genth, John Strong Newberry, William Petit Trowbridge, and George Vasey; and four Foreign Honorary Members, Sir William Bowman, Alphonse Louis Pierre Pyramus De Candolle, Sir Richard Owen, and Alfred, Lord Tennyson.

RESIDENT FELLOWS.

JOHN MONTGOMERY BATCHELDER.

JOHN MONTGOMERY BATCHELDER was born, on October 13, 1811, in New Ipswich, New Hampshire, and died in Cambridge on July 3, 1892. He was a university student at Brunswick in 1831, and also studied civil engineering with Professor Hayward at Harvard University. For many years he pursued the profession of civil engineer at York Mills, Maine; he also practised his profession at Lawrence, Mass., and he had charge of a mill at Ipswich, Mass. His interest in scientific work was recognized by Professor Bache during the period in which he was Superintendent of the United States Coast Survey, and Mr. Batchelder was employed, together with J. E. Hilgard and Joseph Saxton, on elaborate observations to test base-line apparatus. During his connection with the Coast Survey, Mr.

Batchelder made many experimental inquiries, among which were the following: — On the compressibility of rubber. Expansion and contraction of highly calendered paper. On the compressibility of sea water and some other liquids by pressure, and on the effects of temperature in compression in relation to Saxton's sounding instruments. On the use of vulcanized india-rubber in a compression sounding apparatus. On Leonard's dynamometric log for determining the speed of vessels and of currents of water. On the manufacture of braided sounding-line of hemp, saturated with india-rubber. On Saxton's pressure apparatus, and the effect of temperature and rate of cooling when encased in wood. On the effect of inclination on the compensating base apparatus.

In the Coast Survey Report of 1858 it is stated that he prepared ice charts, showing the boundaries of ice during certain years in the harbors of Gloucester, Salem, Marblehead, and New Haven. Professor Bache, in his correspondence with Mr. Batchelder, often expresses very high appreciation of his work and of his abilities.

In 1858 Mr. Batchelder was detailed from the Coast Survey to assist Dr. B. A. Gould in the Dudley Observatory at Albany. His work there, we learn from a letter of Dr. Gould, was "to bring the calculating machine into shape, and also to aid in arranging the telegraphic connections and apparatus." The calculating machine was Scheutz's tabulating engine, and Mr. Batchelder mastered its intricacies and put it in successful operation. The writer of this notice, while a student, well remembers that Mr. Batchelder was pointed out to him as the only man in the country who could work a wonderful calculating machine at Albany.

Mr. Batchelder's mind was essentially scientific; and no one can examine the note-books of observations which he has left without being impressed by his keen interest in the phenomena of nature. Nothing seemed to escape his attention, from the fluctuations of temperature in a well to the quivering of the aurora borealis. In a long series of observations on the temperature of the Saco River, made in 1838, he notes: "I have observed that in extreme cold weather the vapor from the falls has a very sensible effect upon the temperature of the atmosphere, — the mercury commonly standing four or five degrees higher within a few rods of the river than it does at the distance of one fourth of a mile." While at Saco he watched lamprey eels building a dam in the stream, and in an article, carefully descriptive, says: "I noticed in many instances that the heavier stones were lifted by two eels, working alongside of each other, and carried to their

proper places in the structure. Half-bricks weighing two pounds were thus transferred, and many of the stones were of much greater weight." A friend of Mr. Batchelder, a distinguished engineer, to whom these observations on eels were communicated, said in reply: "I have been recently studying cosmic and synthetic philosophy, and looking back, not to final causes exactly where we run plump against the wall, but at any rate some way back, for previous causes and modes of action. Now, I want to know who began, who laid out the work, and acted as boss in the case you describe. From an ex-dam builder."

We repeat this bit of humor to show a peculiar and taking quality of Mr. Batchelder's mind. No matter how dry or technical the business was in which he engaged, he never failed to evoke a sense of humor in those about him. His kindly manner and gentle raillery gave every one an opportunity to effervesce; and no one enjoyed a good laugh more than he who had made the occasion for it. The play of humor in the letters of Professor Benjamin Peirce to Mr. Batchelder, and in the replies of the latter, show this genial receptivity in a marked degree. Professor Peirce's correspondence with Mr. Batchelder extended over many years; and we find the mathematician presenting his theories of tidal action and of cosmical phenomena to the inventor, and the inventor in turn writing of the mechanical appliances which interested his mind so greatly. Thus Professor Peirce, in a letter written in 1855, says: "I highly approve of your dynamometer log, and think it will be of undoubted value. Let me suggest to you to lay it before Bache as soon as possible, for he will find it of the greatest use in the determination of the velocity of currents, and has been seeking this very thing in a totally different way."

In a letter to Professor Joseph Henry, Mr. Batchelder says: "I do not remember any published records of the increase of the temperature of the earth caused by falls of snow and the consequent decrease of radiation. Can you inform me whether such observations have been made? Enclosed is a sheet showing results of observations in my well (at Cambridge, near the Agassiz Museum) during the years 1868, 1869, 1870, and part of 1871; also a rough sketch of the position of the well. Please notice the sudden fall of one degree during the first week in September, 1868, and the sudden rise in the same week in 1870. The observations would have been continued had not the well become dry in consequence of the construction of a deep sewer in the street. If you think that notes of this kind will be of value, I should

like suggestions from you in relation to the proper mode of making them. I suppose the depth should not be great, — say five to ten feet. I propose to drive in the same cellar an iron tube, and allow the thermometer to remain within a few inches of the bottom. The temperature of the surface of the ground should also be recorded. . . . The cost of the apparatus would be about twenty-five dollars, and I should make no charge as observer."

Mr. Batchelder was a contemporary of Agassiz, Wyman, Bond, Gibbs, and Gould, and walked with the men who have contributed so much to make Cambridge a university centre, and aided them often by his practical science. No man ever had greater appreciation of intellectual qualities than he had, and he was always on the lookout for some mechanical paradox to present to his friend, Professor Peirce, or some peculiar fact in natural history to be elucidated by Agassiz or Wyman. Joined to this reverence for pure science was a marked talent for invention. Before 1853 he invented independently the Bunsen burner, which is so indispensable in all laboratories, and which is used so extensively in the arts. His apparatus for deep-sea soundings is still used in the United States Navy, and is highly approved by the British Admiralty. A short while before his death, Mr. Batchelder received from an officer in the English Navy a highly complimentary notice of the performance of his apparatus. His tide-meter for soundings at a distance from the shore has been used by the United States Coast Survey in various places. During the blockade in 1862–63 it was used in eight fathoms of water off Hilton Head, and was instrumental in securing the safety of government vessels. We find among his papers many memoranda in regard to submarine signals, and when he was over seventy years of age he actively carried out experiments on transmitting signals under water by employing water as the medium of propagation of sound instead of the air. By means of the sound of escaping steam he succeeded in transmitting sound over a mile under water. His ultimate object was to give mariners some method of ascertaining the proximity of ships in a fog. The subject of electricity was always a fascinating one to him. In connection with Moses G. Farmer he invented the compound telegraph wire, which consists of a steel core and a sheath of copper. The steel wire was for strength, and the copper covering for electrical conductivity. The inventors made many experiments to coat the steel wire successfully with copper, and finally succeeded. Early realizing the importance, not only of providing telegraphs with a strong wire of good conductibility, but also with an insulator, Mr. Batchelder in-

vented a vulcanite insulator for stringing telegraph wires on poles or other supports. This insulator was used on the telegraph between Boston and Portland in 1853, and between San Francisco and Sacramento in 1854. His electro-magnetic watch-clock is now in use in various places, — notably in safety deposit vaults. The Batchelder dynamometer for the measurement of power was one of the earliest forms of practical dynamometers, and was of very ingenious construction. It was well adapted for the measurement of the power consumed in various forms of mill machinery. Among Mr. Batchelder's other inventions are the following: —

Vulcanite plate electric machine.

Pressure sounding machine.

Tide gauge hydrometer.

Cards for the blind.

Card catalogues for libraries.

Porcelain and iron insulator.

Instrument for drawing curves.

Railway station and starting signal.

Iridium surface copper plates. The first plate of large size, 21 × 16 inches, was exposed twenty-seven years without wax or other preparation, and was found still brilliant and uninjured.

Hygrometer for regulating moisture in closed apartments and in greenhouses.

Oat basket for horses. To keep the feed at a uniform level, to prevent waste, and to allow the horse to breathe freely.

One cannot read the above list without being impressed by the remarkable activity of Mr. Batchelder's mind. His note-books teem with suggestions, and even in his eightieth year he made memoranda and suggestions for future work. The writer of this notice remembers to have received at the same time two letters: one from Mr. Batchelder, then in his eightieth year, in which he asks if it is possible to make a magnet six feet long; and another from Moses G. Farmer, who had been many years stricken with paralysis, and had to be wheeled about in a chair, in which keen interest was expressed in regard to the oscillatory nature of electrical discharges. Thus two lifelong friends rose superior to the ills of old age, and manifested a calm cheerfulness and scientific philosophy of life. No one could meet Mr. Batchelder in the closing years of his busy life without gaining a conviction that there was something undying in the spirit that could so cheerfully meet the growing infirmities of age. When his last illness was unmistakably upon him, he took the writer into the cellar, —

picking his steps painfully down the stairway, and saying humorously, "Slow but sure," — in order to show an apparatus for testing the daily variations of the magnetic compass.

Mr. Batchelder was elected a Fellow of the Academy in 1866. He was also a member of the Boston Society of Natural History, of the Boston Society of Arts, of the American Association for the Advancement of Science, of the American Institute of New York, and of the Natural History Society of Portland, Maine.

1893. JOHN TROWBRIDGE.

HENRY INGERSOLL BOWDITCH.

DR. HENRY INGERSOLL BOWDITCH died on January 14, 1892, after a life of unusually varied interests and activities, in the eighty-fourth year of his age. His illness, although not disabling until the last year or two of his life, had been long and distressing, and, with the added infirmities of age, the years of waiting became weary, especially after the death, in December, 1890, of his beloved companion for more than half a century. But he did not lose his cheerfulness or his courage. His generous thoughtfulness of others and his fine serenity of mind remained to the last. As he read or quoted a favorite passage from the "De Senectute," the old fire flashed from his eyes almost undimmed. To those whose privilege it was to be near him the example of his death will always be an inspiring memory.

Dr. Bowditch was born in Salem, Massachusetts, on August 9, 1808. His father, Nathaniel Bowditch, the eminent mathematician, was a man of sterling virtues, whose own early struggles for an education had impressed upon him the value of self-discipline and the vanity of such accomplishments as music, for instance, which he regarded as worse than useless in building up character. He had not, however, the Puritanic or the Calvinistic austerity so common in New England in his day. He believed in young people having a good time in a healthy, sturdy sort of way. Few sons could say as much as Dr. Bowditch said with a good deal of fervor, that the only mistake which his father had made for him, in his estimation, was his attitude towards music. Dr. Bowditch's mother was Mary Ingersoll, the beauty of whose life was reflected in her influence upon her home and her children. Under such parental guidance, and with the companionship of three brothers and two sisters very like him in possessing an inheritance of individuality and force, and all united in a strong bond of family affection, his child life was ideal.

He attended the Salem schools until the age of fifteen, and then the Latin School in Boston, his father having removed to that city in 1823 to become Actuary of the Massachusetts Hospital Life Insurance Company. No especial interest was awakened in Dr. Bowditch at school, and there is nothing noteworthy to be said of him there, except that he showed the faithfulness to his duties inculcated by his parents' precepts and example. He used to say that he was not then fond of books, but he gained more than respectable rank. At the exercises of the Green Street School in Salem, in 1822, he was assigned a Latin dialogue. He was generous, sympathetic, truthful, manly, thoroughly a boy, and always ready for fun or for the front of one of the fights then not uncommon between the boys of the opposing sections of the town.

In view of some supposed family tendencies to pulmonary disease, his father, with a knowledge of Nature's laws unusual at that time, and with a practical sagacity which marked his whole career, insisted upon an open-air life, from which he and his children gained sound minds in healthy bodies. The simple living, the early love of nature, the habits of industry and self-denial, so common to the New England life of that time, developed in Dr. Bowditch a thoughtfulness, self-reliance, independence of mind, and vigor of action, which have become more rare with the increase of wealth and luxury.

He entered Harvard as a Sophomore, and graduated in 1828, taking the degree of A. M. later. He had an alert, receptive mind, and was a faithful student, but there was little in his college life to arouse his enthusiasm. He took part in a Latin dialogue at the Junior Exhibition, and had a Conference at Commencement. He was known as being of a rather retiring disposition, a warm-hearted good fellow, industrious, straightforward, impulsive, pugnacious if his ideas of truth or right were assailed, but not obstinate. He was ardent, of quick sensibilities, respected, and always to be depended upon. He had not then the spirit of the reformer.

The years of study for his degree in the profession of his deliberate choice, including a service as house physician at the Massachusetts General Hospital from 1830 to 1831, proved an incentive to his best efforts, and he worked with persistence and devotion. He thought himself favored in having been under the influence of the brilliant intellect of Jacob Bigelow, and the painstaking practical wisdom of James Jackson. The scientific exactness of the one attracted him, as did the conscientious sense of duty of the other. John Ware's quiet, judicial mind made less impression upon him. These three men did much to shape his medical character, so to speak. He pre-

served full notes of their lectures, and often referred to the habit thus formed as having been of immense value to him in the exact knowledge of his patients which his records of their cases gave him. Dr. Bowditch chose medicine rather than surgery, because its problems interested him more, and because he had a great repugnance to using the surgeon's knife.

When he went to Paris to continue his medical studies, in 1832, his character and training had prepared him for the precise methods of observation, and the faithful record and accurate analysis of facts, as the true basis of medical knowledge and practice, in which Louis, one of the first to protest against the medical dogmatism of the day, was then indoctrinating his pupils, — "My beloved master in medicine," he said of him, "whose noble example will always lead every honest scholar to a reverent regard for scientific truth, whose works have been to me a stimulus to patient labors in my profession, and whose friendship was to me a lifelong delight." He received his degree of M. D. in 1833, and joined the Massachusetts Medical Society in 1835.

While in Europe, another marked influence upon his character came from his study of French life, in which he found much to admire. Through his father's translation of the "Mécanique Céleste," he became acquainted with the Laplace family and others, who made a deep impression upon the young American. But, of course, there was already in him that which responded readily to the suggestion from their example of courteous consideration to every one. As he expressed it, the Frenchman said with a polite gesture, "You are as good as I"; but the American, "—— you, I am as good as you are." This lesson he never forgot. His attentive and respectful consideration for the opinions of others, no matter how immature or inadequate, has been an encouragement to many a young doctor, for which he ever held Dr. Bowditch in grateful remembrance. His poorest patients received the same polite attention and thorough examination as the most distinguished. They were all fellow beings needing help, and he regarded it as his solemn duty, as well as his pleasure, to give them his best. Whether they paid his full fee, or a half or a quarter or a twentieth, or nothing, he rendered the service cheerfully. When he declined to accept any part or all of his fee, it was with such delicacy of feeling that the most sensitive woman could only gratefully receive his gift.

After establishing himself in Boston, in 1834, and while waiting for practice, he devoted much time to benevolent work and took great pleasure in helping those who needed encouragement or assistance, —

interests which he kept up to the last. He was associated with his classmate, Charles F. Barnard, in the Warren Street Chapel for the education and elevation of the children of the poor, and was superintendent of its Sunday school. Quite late in his life the boys and girls used to come to his office on Saturday afternoons with their little earnings for the savings-bank books which he kept for them. The Unitarian religion then awakening in New England, and its leader, Channing, deeply interested him. But he soon outgrew even their limitations, to know no religious creed except that which was common to all who strove to lead pure and noble lives, whether Catholic, Protestant, or Agnostic. While investigating the Lymnæa his microscope was his "noblest cathedral for the highest religious thought," he said.

In 1835, he met one of the great turning points of his life in having by chance been an eyewitness of the famous Garrison mob, during which the young Antislavery agitator was lodged in the Leverett Street jail in Boston, for security from the mob, "composed of gentlemen of property and standing," as it was designated by one of the leading newspapers the next day (October 22). Boiling with indignation, Dr. Bowditch determined to devote his "whole heart to the abolition of that monster slavery. But," he adds in his diary, "even Antislavery has never taken me away from constant labor for the elevation of medicine." When he became an Abolitionist, church, state, the Constitution and laws of the country, old friendships, and social ties were against him. He was mocked, sneered at, passed on the street without recognition by his father's old friends; but his courage never faltered, his faith in humanity and the final triumph of his cause never failed. Without even any feeling of bitterness for such opponents, he labored steadily on, with pistol in one hand carrying the runaway slave in his chaise to a place of safety; working for the fugitive slave Latimer, arrested and returned from Boston in 1842; agitating the "Great Massachusetts Petition," as a result of which a law was passed forbidding the use of our State jails to detain fugitive slaves, and prohibiting our State officers from helping to return them; a member of the Vigilance Committee in 1846 and in 1850; secretary of the Faneuil Hall Committee in 1846, which appealed to public opinion in Massachusetts on the encroachments of the slave power; and a co-worker with Parker and Phillips and Garrison in arousing the conscience of the nation. Boston was then a small city, and its "society" was rigid and autocratic. The conservative part of the community, accused too by the Abolitionists of being subservient to the

South, was shocked by what it regarded as revolutionary, lawless, and not respectable methods of agitating a reform that was generally desired by the North; and its ostracism, for the time, of such men as Dr. Bowditch, Charles Sumner, and Edmund Quincy, "learned in those arts that make a gentleman," as Lowell said of him, is evidence of the intensity of its opposition and of the courage needed to face it.

When an escaped slave, Anthony Burns, was given up to his master in May, 1854, and taken in fetters down Court and State Streets with "an overwhelming force of soldiers," State and national, Dr. Bowditch dashed past the police on guard, under the rope stretched across Tremont Street, through the cordon line, at the head of a crowd of excited citizens, down to the wharf, where a devoted band of Abolitionists stood in horror to see the tug bearing the returned slave steam away to the United States cutter, which carried back to slavery the negro who had been given up to his former master by the United States judge in Massachusetts. In describing this scene, Dr. Bowditch showed all the fire and pathos of the orator. One could feel the death-like silence that came over that little group, willing to be called fanatics and radicals and iconoclasts, but determined not to abate in the least their fight against a great national crime. Then and there, with a contempt for legalities and an utter disregard of conventional public opinion, they vowed that such a disgrace should never again happen to the soil of Massachusetts. At Dr. Bowditch's instigation they formed the Anti-man-hunting League, a secret oath-bound club, with twenty-four lodges in as many towns, and four hundred and sixty-nine members armed with billies and trained by frequent drills for capturing and carrying off to one of their places for concealment any slaveholder who should come to the State to hunt and reclaim a runaway slave. Dr. Bowditch was the secretary, and their records were kept in cipher. "Wrong-headed and absurd as the plan may seem to many, if not all, 'reasonable' persons," he said, "I am proud to remember that I was among the first of those who advocated physical resistance to slavery as we saw it in the North."

Less than a decade later he saw Colonel Shaw march down Court Street at the head of his negro regiment; he lived to see slavery abolished, peace and industry established in the South, and himself honored at the North with Phillips and Garrison, and loved by his Southern associates. He had been a hard hitter in the fight. When once asked his political opinions while on the "sacred soil of Virginia" serving as a volunteer, in answer to the call for aid for the wounded after the second battle of Bull Run, he said, "Wendell Phillips is a proslavery

man compared with me." In 1842 he wrote a remarkable letter to a Southern physician requesting a consultation, in which he declined to have "commercial relations for pecuniary profit with slaveholders." As soon as the struggle was over, the same impassioned lover of humanity, he bent his energies to the restoration of good feeling between the North and the South, a work in which he had an opportunity to do excellent service at the annual meetings of the American Medical Association, which brought together physicians and surgeons from all sections of the country. In his home he received men who had owned slaves with the delightful hospitality of warm friendship.

Throughout his life, Dr. Bowditch referred to his antislavery work with thankfulness that he was permitted to contribute his part to such a crisis of the country's history, and with gratitude for its influence in arousing his public spirit, in forming his character, and in shaping his life-work. He entered into his professional duties with the same ardor. He was, upon his return from Europe in 1834, admitted into the leading medical society in the city, the Boston Society for Medical Improvement. The following year he and Professor John Ware organized a Society for Medical Observation, the other members of which were students, which was discontinued in 1838. A few years later, with a few other physicians, he formed private medical classes, in which, in addition to his other duties, he demonstrated autopsies at the Massachusetts General Hospital. It is superfluous to say that, with these opportunities as a teacher, he labored strenuously in extending Louis's methods of careful study, close, exact observation, and rigid inductive reasoning. His early medical publications, from 1836 to 1838, showed also the bent of his energies, being translations from Louis, and in defence or in praise of his work in the study of disease. Before he received any appointment at the hospital, he was a frequent visitor in the wards, and the value of his examinations of the patients by percussion and auscultation, then new in Boston, is testified to by Dr. Morrill Wyman, who was, in 1836, house physician there.

In 1838, Dr. Bowditch married Olivia Yardley, of London, whose acquaintance, made in Paris, he regarded as the great blessing of his life. Her character was a beautiful complement of his, and her steady, cheerful influence was often a wholesome guide to his impulsiveness. He was in that respect like his friend Wendell Phillips, who even said that he owed his whole career to his wife.

He became admitting physician, 1838 to 1845, and later, 1846 to 1864, visiting physician at the Massachusetts General Hospital; the first visiting physician at the Carney Hospital, 1863; visiting physi-

cian at the Boston City Hospital, 1868 to 1871; consulting physician to the Massachusetts General, City, Carney, and New England hospitals. He was Professor of Clinical Medicine in the Harvard Medical School from 1859 to 1867. He was elected President of the American Medical Association in 1876. In addition to his Fellowship in the Academy, he was a member of the American Association for the Advancement of Science, of the American Public Health Association, of the American Academy of Medicine, of the Paris Obstetrical Society, of the Paris Society of Public Hygiene, of the Boston Society of Natural History, of the leading medical societies in Boston, and honorary member of the Royal Italian Society of Hygiene, of the Association of American Physicians, of the New York Academy of Medicine, of the Philadelphia College of Physicians, and of the New York, Rhode Island, and Connecticut State Medical Societies.

When he was appointed admitting physician, negroes were not received as patients in the hospital. He offered a test case of pneumonia, resigned his position when his negro patient was not admitted, and carried his point, his resignation not being accepted. He never was one who "fears his fate too much."

His loyalty to his profession, his unfailing fidelity to his duties as hospital physician, his full and painstaking visits, thoroughly examining every organ as well as scrutinizing most minutely every symptom in his patients, and his kindly, sympathetic, courteous devotion to them personally, have been reflected in the professional lives and characters of his pupils throughout the land. As Professor, he taught his students to be honorable, honest, uncompromisingly truthful, courageous, careful, thorough investigators, and, whatever they did, never to forfeit their own self-respect. He insisted, too, that they should treat their patients personally fully as much as their diseases, and to use hope, faith, and enthusiasm as an important part of their materia medica. This service they returned with a love and respect that is accorded to few teachers. His colleagues, many of whom were younger men with fewer demands upon them, admired the lavish expenditure of time which he gave to others and to his hospital work. Few men of established reputation would spend hours, as he often did, to see an interesting case with a dispensary physician in the slums, or to help with his advice.

In 1846 he was the leading one of eight physicians* to found the

* Henry I. Bowditch, Charles E. Buckingham, George Derby, John D. Fisher, Samuel Kneeland, Jr., Fitch E. Oliver, William H. Thayer, and John B. Walker.

Boston Society for Medical Observation, and the meetings for organization were held at his house. The object of the society was the reading of original papers, and such unsparing criticism that at least one member resigned because he could not stand it. It was after the plan of the Society for Medical Observation in Paris, of which Louis was President, "to make its members good observers of disease, to collect and arrange accurately recorded facts in furtherance of the cause of medical science, and to publish from time to time the results of the examination of such facts." In the Boylston Medical School,* where he taught auscultation and percussion from 1852 to 1855, the instruction was so excellent that the school was in danger of becoming an important rival to the Harvard Medical School, and ceased to exist by being to a great extent absorbed in it. In his private office Dr. Bowditch was always to his assistants the same high-minded friend as to his pupils in the Medical School, ever trying to help them, especially those most needing assistance of any kind. He taught them not only how to diagnosticate diseases, but also, incidentally by his example, how to talk to and treat people, although he lacked to a fault the faculty of adapting himself or his advice to the individuality of his patients. He was so firm in his own strength that he was not always patient with weak people, or with the weaknesses of strong people. He was too honest and direct to study their whims and peculiarities of temper or temperament as a means of increasing his practice. The privilege of being with him as assistant was eagerly sought for by medical students. He was essentially a physician and a teacher of medicine. His calling, which he regarded as the noblest work that man might do, was so deeply impressed upon his whole being that it could not be wholly lost sight of even in his character as a public-spirited citizen or as a zealous and intense reformer. One can hardly place a limit to his interests, or measure which was larger, his great heart or his active brain. Few physicians have lived whom so many have delighted to call their friend. He showed the same large sympathy as in his profession while he was one of the Directors of the Boston Co-operative Building Association for improving the dwellings of the poor, and the same spirit of helpfulness in passing evenings at the notorious old tenement called the "Crystal Palace," to teach the rudiments of what later developed into greater proportions as our system of industrial

* The Faculty of the School consisted of John Bacon, Jr., Charles E. Buckingham, Henry G. Clark, Edward H. Clarke, John C. Dalton, Jr., George H. Gay, and Henry W. Williams. Several of these men became Professors in the Harvard Medical School.

education. His simple character was in singular contrast to his complex life.

He had for some time been physician to the St. Vincent Orphan Asylum, which was under the charge of "that most remarkable woman," as he called his friend the Sister Superior Anne Alexis, when she undertook to establish a general hospital under the control of a Catholic sisterhood. She naturally went to Dr. Bowditch, who said of her, "We were like brother and sister," for help in organizing the medical staff. To his cordial aid, to his willingness to endure much from inexperience on the one hand and from religious prejudice on the other, and to his patience in bearing the annoyances connected with founding such a charity from small beginnings, with too little money, the Carney Hospital, now after thirty years large and prosperous, owes an inestimable debt of gratitude. He was made President of the medical staff of the hospital as soon as it was opened.

In 1848, at the age of forty, Dr. Bowditch was elected a Fellow of the American Academy of Arts and Sciences. For full forty years he attended the meetings most zealously, listening with keen enjoyment to men the list of whose names includes Wyman, Gray, Agassiz, Peirce, Gibbs, and Rogers. His communications were three: on the Lymnæa, in 1848; on the Results of Investigations as to the Preservation of the Teeth, in 1849; and on Pulmonary Consumption, as influenced by certain Climatic Conditions, in 1870. Of the paper covering his four years' investigations on the Lymnæa, the manuscript of which fills 117 folio pages, closely written, with copious illustrations, he said: "Soon after showing the paper to Agassiz, I was chosen into the American Academy of Arts and Sciences, with, as I have reason to believe, Agassiz as one of my sponsors. The Professor commended the paper and said to me, 'You show us the development of the snail after leaving the ovary of its parent. To make the cycle complete, you should now show us the gradual development of the ovum in the ovary of the adult.' Accordingly I tore one or two of the living snails to see the ovary *in situ*. But I soon found vivisection, even of this humble creature, very distasteful and painful to me, and, as I did not think that any beneficial result would come from the work, I let the 'cyclo' remain incomplete."

In 1852, through au injury in an obstetric operation followed by a long illness with septic infection, a finger of his right hand was permanently disabled. He then gave up midwifery and general family practice, devoting himself more especially to thoracic diseases,

in which he was soon regarded as the leading specialist in New England, with only one rival in this country, Dr. Austin Flint of New York. His consultations, however, to a great extent covered the whole range of internal medicine.

In 1879, when seventy-one years old, he fell in stepping from a horse car to an icy street and separated the tendon from the patella. The injury, the shock, and the six weeks of enforced rest in bed in a constrained position were a terrible strain, the effects of which so incessantly active and sensitive a temperament as his could not but feel. He was slow in regaining his old vigor, and thereafter always had a slight physical disability of gait which gave him an appearance of infirmity of age that was not altogether real, and which the alertness of his mind quickly disproved. In the mean time epileptiform attacks, naturally of a distressing nature, which seemed to be the result of this fall, appeared and recurred, sometimes at such long intervals that it was thought they had ceased, and again with discouraging frequency. Few even of those who knew him well can conceive how great this trial was, or what fortitude he showed in meeting it. All the faith and hope and strength and courage in his nature came out only the stronger. As he became more calmly contemplative, there were fewer of his vigorous explosions of feeling and splendid outbursts of impulsive enthusiasm, while the interests of his life remained as active as ever. The more frequent vacations which he found that he needed gave him his long-coveted leisure to indulge his love of nature and of reading, and especially of music, of which he was devotedly fond all through his life, and to be more with his family. He continued his assiduous attendance at medical society meetings until the impaired hearing of eighty years compelled him reluctantly to give them up, and still later he occasionally saw patients in consultation. It has been suggested that it may have been because he was so busy that he never used tobacco, but it is more consistent with his character that he should have abstained from its use for the same reason that he took wine only with the greatest moderation.

After he had become of the first eminence in his branch of the medical profession, and his reputation had extended throughout this country and Europe, he still kept in close touch, through the Thursday Club and constant attendance on scientific and medical society meetings, with the spirit of progress in all branches of knowledge. Whatever interested humanity interested him. He gave his assistance freely to all movements to elevate mankind, regardless of race

or creed. When his fame was at its zenith, probably even his own family did not learn, when his quick eye of sympathy had seen so many ways to help, that after a long day's work he had given away far more than the amount of his fees, so little did his right hand know what his left hand was doing. He gave himself freely and gladly with his gift. How many soldiers' widows went from his office without being allowed to pay any fee for his advice! It is true that his generosity was imposed upon, but his almost instinctive recognition of what was base, and his contempt for it, often saved him from impostors.

To his professional associates he was an inspiration; to the younger men his unfailing kindness of heart and generosity gave strength and courage; the example of his life raised them to a higher plane of living. To one who had sought advice from many older physicians, and had heard how to get practice and fame and wealth, Dr. Bowditch's words were: "Never do anything which will make you think afterwards that you have been a sneak."

Even before the surgeons, in 1850, he successfully operated for empyema, and in later years he fairly lost patience with them for being so slow to take up laparotomy for abdominal and pelvic tumors and abscesses. To one surgeon whom he considered one of the boldest, but who was not willing to open a perinephritic abscess, he proposed, in 1871, himself to push in the scalpel where the surgeon pointed out the proper spot. In sanitary science, too, he led the way. With the eloquence of sincerity, showing to a committee of the Legislature his chart indicating the prevalence of pulmonary consumption in Massachusetts, he explained to them the law which he discovered of its relation to soil moisture, giving them in detail the results of his painstaking investigations upon the relation of soil moisture to pulmonary consumption, as embodied in the annual address to the Massachusetts Medical Society, which he delivered in 1862. In indicating to the Legislature how much could be and had been done, by regarding this law, to save human life, he chiefly persuaded them to create the first State Board of Health in this country, an example which thirty States have followed. When the board was appointed, in 1869, Dr. Bowditch was easily first in the estimation of the medical profession and the community for the arduous and responsible duties of its President, a position which he retained, at great sacrifice of his time and professional income, until 1879. When the powerful interests attacked by the board in the cause of the public health resisted, and the politicians threatened, and other members of the board hesitated, ardent

and impulsive, he pushed on until the point was gained. His very impatience was often a virtue, and a power for good. If his enthusiasm carried him too fast or too far, he was ready to modify his course. If in his vehement indignation and scathing rebuke of anything which he considered mean or unworthy he had seemed to wrong any one, he was quick with generous redress. His apologies for his own haste were as frank as his magnanimity was noble. His simplicity and earnestness were so transparent, that, as one of the members of the board said, there could be no real dissension in a board of which he was the chairman; and his sense of humor, love of fun, and quick intuition helped him out of many difficult places. He liberally contributed sanitary papers to the reports of the board. Every subject considered by them bore the marks of his conscientious study. After the political timidity excited by a Butler campaign had swamped the board in a Board of Health, Lunacy, and Charity, in 1879, he felt obliged to resign his membership in it, "as a protest" against the "grotesque alliance," as soon as a sufficient experience of the new board had failed to change his opinion of the folly of it all. He still labored for the repeal of the obnoxious law, as he had worked to prevent its enactment, and he did much, not only for the restoration of the old State Board of Health, but for placing it upon a higher plane of usefulness than ever before. This he accomplished by appealing to and arousing public sentiment, in the intelligence and honesty of which he never lost faith.

When the yellow-fever epidemic of 1878 aroused the nation to the need of a National Board of Health, the chairmanship seemod the opportunity of Dr. Bowditch's life. No one else had the personal qualities and the reputation to fill the place. Unfortunately, the state of his health prevented his accepting it, or indeed of serving as a member of the board for more than a year; and there followed its melancholy wreck, which so many thought that he might have averted if he had been chairman.

He was one of the earliest advocates of specialties in medicine in this country, freely asking the advice of men much younger than himself, and treating with respect the sincere opinions of the least experienced, if given, as he gave his opinions, without assumption. He was one of the first to believe in women as physicians, and thought it but justice to them, as well as good policy for the community, to give to them the same advantages of study as to men.

More than ninety thousand manuscript pages of records of cases of private patients, ten printed papers, and sixty-six pamphlets printed

in twenty-nine journals or society transactions, with numberless short articles on various subjects, attest the industry of his life. His letters and notes and diaries are full of his work, with scarcely a mention of his honors. He was so generous in the appreciation of what others had done that he was constantly giving them praise which really belonged to himself. His epoch-making work in medicine was his thoracentesis, his first operation with the Wyman aspirator having been done in 1850, some time after Dr. Morrill Wyman's "brilliant operation." He always gave Dr. Wyman the credit of having discovered the means of accomplishing this object, for which he had himself long sought. But he recognized its value at once, and made such frequent use of it as to demonstrate its merit fully, and to compel its adoption. His publications upon this subject probably extended his reputation more among physicians than any other of his writings.

Dr. Bowditch revisited Europe in 1859, 1867, and 1870. He enjoyed these vacations with boyish intensity, entering into the pleasures afforded by leisure, art, science, literature, music, reviving his old college love of the classics, renewing former friendships, and forming new ties. In the earlier of these visits he introduced thoracentesis for pleural effusions with such earnestness that it was first taken up by Budd of London and Gairdner of Glasgow, and then became generally adopted in Great Britain, and later upon the continent of Europe. Precisely as in this country, its merit was for a long time doubted, and it was regarded as being too full of risk, until Dr. Bowditch's large experience, and his reiterated papers and reports of his results from it, forced a recognition of its value upon the medical profession. In his last visit he gained the admiring friendship of Simon and Buchanan, and made the work of our State Board of Health known and respected in England.

Dr. Bowditch's greatest title to honor from his professional associates was his character. An earnest searcher after truth, he stimulated and encouraged good work in others. Eager to keep abreast of all the advances in medical science, and to further its progress, he sought out the workers among the younger men, to learn from them, and to inspire them with courage to go on with their work. Honest, fearless, outspoken, he made friends of his enemies by the simplicity, purity, sincerity, and unselfishness of his purpose. He compelled an admiration of the right and a hatred of wrong. At the meetings of the American Medical Association, at which he was constant in attendance so long as his health permitted, men from Maine to California caught the spirit of his enthusiasm; they felt the stimulus of

his eager search for the truth; they were so filled with admiration of his noble life that they went back to their work with a higher sense of personal duty and professional obligation. Not the least of his services to his profession was his condemnation of a narrow medical etiquette, and his untiring insistance that the interests of the patient should be the physician's first and most sacred obligation. He knew, of course, that he lost consultations thereby, just as he lost patients, by always refusing to compromise his self-respect. But he was candid and generous to his colleagues, ready to be convinced if his way were not the best, and quite willing to allow a wide latitude for differences of opinion. He did more than any other man of his generation to lift the medical profession above the imputation of being merely a trade, because he more than any other could divest himself of his personality, and look at his patient from the point of view of the patient's interest. The conduct of his life was above the thought of any gain to his personal reputation.

In No. 46 of the Bibliographical Contributions published by Mr. Justin Winsor, the distinguished Librarian of Harvard University, comprising the work of the Class of 1828, of which Dr. Bowditch was Class Secretary after the death of his classmate Barnard, there is a list of one hundred and sixty-six titles of Dr. Bowditch's writings since his graduation in medicine. This list, compiled by him in the last years of his life, when his health no longer permitted active work, includes a very great variety of subjects, a few of which are in manuscript, or consist mainly of collections of cuttings from newspapers, etc. Those of permanent professional interest are on pulmonary consumption, reports of medical cases, on thoracentesis for pleural effusion, and on matters of public health, including his Centennial Address delivered at the Medical Congress in Philadelphia in 1876. This address was, by vote of the Congress, sent to the Governors of all our States and Territories, to be transmitted to all the Legislatures and to all the Sanitary Boards and State Medical Societies in the United States and Canada. Throughout these writings, most of them prepared in odd moments snatched from a busy life, one sees the quick response to every fine sentiment, the "greater force from a certain inspiration which compels me to act and to speak."

During our civil war, Dr. Bowditch was an untiring worker in numberless ways. As enrolling surgeon his examinations of recruits were thorough, made in a kind and tender way, with an affectionate "God bless you!" as his parting word, given with the same intense earnestness as he marked with nitric acid a D on the back of a de-

serter from the Union army. To him more than to any other single individual was due the persistent effort which, strange to say, was necessary in order to compel Congress to pass the law creating an efficient ambulance service in the army. The ardor of the patriot accepted the loss of the son bearing his grandfather's name, killed while leading a squadron of cavalry at Kelly's Ford; but to the father's love it was a lifelong grief, how deep few only could know.

Of Dr. Bowditch's home life, one of his friends writes, "I think of his home as more filled with love than any other home I ever knew." It was so full of the spirit of generous and charming hospitality as to make it one "which all who were privileged to enter it must ever remember with admiring and grateful love." In one respect Dr. Bowditch possessed a remarkably judicial mind, in that he clearly recognized his own defects. Indeed, he was not only always modest and free from self-assertion, but he was his own severest critic, even where others saw only cause for praise. He was charitable in his estimate of everybody but himself. When he erred in judgment, he did so from spontaneous self-forgetfulness born of a righteous impulse. He was so genuine and so human that "his very faults were endearing."

The perspective of years will be needed to estimate justly Dr. Bowditch's life and work. He did not possess the striking originality, the uniformly calm judgment, the brilliant intellectual genius, the keen therapeutic insight, or the rigid presence of mind and patient self-control, of one or another of his contemporaries. But he had a kind of wisdom, a directness of intuition, foresight, breadth of view, and largeness of nature, with absolute independence, uncompromising honesty, energy, enthusiasm, and marvellous industry, joined to the genius for investigation and to the scientific and humane spirit, that place him as the great man of the medical profession of New England in his day, as he was, at the height of his reputation, our most eminent physician.

The following memorandum of Dr. Bowditch's "life-work," abbreviated from Mr. Winsor's Bibliographical Contributions, although prepared by himself for his class-book, is not absolutely complete; but probably the omissions are not many, except possibly of letters and short articles for newspapers, etc. His comments on one title after another are characteristic, and full of interest, but too long to be reproduced here.

Translation of Louis on Typhoid Fever. 2 vols.
Translation of Louis on Phthisis. (Cowan's, amended.) 1 vol.
Reminiscences of Dr. Jackson, Jr., and of Charles C. Emerson (my classmates).
Translation of Maunoir on Cataract.
Translation of Louis's "Proper Method of Examining a Patient."
Medical Records of every Patient treated from 1839 till 1887.
Remarks on Dr. Martyn Paine's unjust Criticism of Louis and of his "Numerical Method."
Rejoinder to Martyn Paine.
Life of Nathaniel Bowditch, LL.D., for children, prepared at the request of Hon. Horace Mann.
Short Sentences on Auscultation.
Dr. Ricaud, Correspondence with, declining to have Commercial Relations for Pecuniary Profit with Slaveholders.
The Latimer Case.
Trichina spiralis.
Lymnæa.
A League for Freedom.
History of the Establishment of the Boston Society for Medical Observation.
The Young Stethoscopist. A small Pocket "Vade Mecum" for Students and Practitioners. With Plates.
Introductory Lecture to a Course of Clinical Lectures at the Massachusetts General Hospital.
Umbilical Hemorrhage in New-born Children.
Malignant Disease cured by a Bread and Milk Diet.
Preface to Ancient Fortification in Ohio, with a Plan by Winthrop Sargent in 1787.
Memoir of Amos Twitchell, M. D., with an Appendix containing his Addresses.
Thoracentesis in Pleural Effusions. — Separate print, New York. — Separate print, Boston. — Twelve Years' Experience. — Before New York Academy of Medicine. — Letters to Dr. Clifford. — Letters to Dr. Holiday, Cincinnati. — Remarks, Surg. Section Am. Med. Assoc. — Dangers, etc.
Two Fatal Cases of Pleurisy. Would not Thoracentesis have saved Life?
Value of Antiseptics in Empyema.
Case of Dilated Bronchi. Autopsy.
Report of a Committee of the Suffolk District Medical Society on Intermittent Fever in Chelsea.
A Treatise on Diaphragmatic Hernia.
Anti-man-hunting League (*cujus pars fui*) Records, etc.
Cases of an Anomalous Development of Tubercles at the Base of the Lung resembling Pneumonia. Separately printed.

Canoe Trip down the Penobscot from the Headwaters to Bangor.
Journey to and Residence at the Isles of Shoals.
Raw Pork as an Aliment. Separate print.
Life and Character of James Deane. An Address (Aug. 4) at Greenfield.
Circular to the Patrons of the Bowditch Library, with the Documents on the Occasion of its being presented to the Public Library of the City of Boston. Signed by Dr. Bowditch, with the other sons of Nathaniel Bowditch, LL. D.
Burns Centennial. Speech. Published in the Proceedings of the Committee.
Double Aortic Aneurism; a Cause of Lung Disease.
Peculiar Aneurism of the Left Ventricle of the Heart. Case.
Songs of the People during the War of the Rebellion.
Memorials of Massachusetts Soldiers, etc., who fell during the Rebellion.
Journey to Mount Desert, Me.
Topographical Distribution and Local Origin of Consumption in Massachusetts. In Medical Communications of Mass. Med. Soc.; and separately printed.
Report to William J. Dale, Surgeon-General, Massachusetts.
Letter to Governor Andrew on the Hospitals in and around Washington, D. C.
Seven Pamphlets on the Urgent Need of an Ambulance Corps of Men trained to take Care of our Wounded Soldiers.
Sketch of the Life and Character of Nathaniel Bowditch, LL. D., made at the Dedication of the Bowditch School.
Journey to the Saranac Lakes.
Apology for the Medical Profession as a Means of developing the whole Nature of Man (as a Physical, Intellectual, Moral, and Religious Being). Address to the Students of the Harvard Medical School, and published at their Request. With Additional Remarks on a Topic of Importance at the present Hour.
A Brief Plea for an Ambulance System for the Army of the United States, as drawn from the Extra Sufferings of the late Lieutenant Bowditch and a Wounded Comrade.
The Ambulance System.
Is Consumption ever Contagious? A Paper prepared for the Boston Society for Medical Observation.
Reception by the Teachers and Pupils of Notre Dame Academy.
Journey to and Residence among the Saranac Lakes.
Memorials of Lieut. Nathaniel Bowditch, A. A. G. of First Cavalry Brigade, Second Division, Army of the Potomac, killed while leading a Charge at Kelly's Ford. Privately printed, 50 copies.
Memoir of the same, with many Illustrations, Photographs, etc.
Four Volumes of Letters to and from Lieut. Nathaniel Bowditch and others, received after his fall. My Journals of Visits "to the Front" and to Battlefields, etc.

Review of Dr. Horace Green's Work on Consumption. Topical Applications to the Throat.

Report on the Boston Public Library by the Examining Committee.

Aortic Aneurism. Treatment, Rest, Venesection, Diet.

American Medical Association at Cincinnati.

Paris Abattoir: Hippophagic Banquet.

Journal: Visit to Europe.

Hippophagy.

Cases of Perinephritic Abscess and its Treatment. Read before the Boston Society for Medical Observation

Consumption in New England and elsewhere; or Soil Moisture one of its chief Causes.

Down the St. Lawrence and up the Saguenay.

Report of the Committee on Climatology and Epidemics in Massachusetts.

Consumption in America.

Remarks at the First Meeting of the State Board of Health of Massachusetts.

Just Claims of Morton as Discoverer of Etherization.

Appeal made by the Carney Hospital.

Medical Testimony and Experts. A Report to the Suffolk District Medical Society.

Visit to Europe. (H. I. and O. B.)

Perinephritic Abscess; Lung Disease and Pleurisy.

Letter from the Chairman of the State Board of Health concerning Houses for the People, Convalescent Homes, and the Sewage Questions.

Letter to the London Medical Times and Gazette, Criticisms of Oppolzer and Niemeyer's Inefficient Treatment of Perinephritic Abscess.

Thoracentesis and its General Results during Twenty Years of Professional Life. Remarks made at a Meeting of the New York Academy of Medicine, April 7, 1870. Published by Order of the Academy.

Papers, annually, in Reports of Board of Health, 1st to 7th inclusive. (*Vide* below.)

Intemperance. Circular to the U. S. Consuls in Foreign Countries. Analysis of Returns, and Deduction of a Cosmic Law.

Night Stroll in London and Boston.

Peabody Buildings for the Poor. Miss Hill.

Sewage, etc. Ruskin's Organized Work.

Convalescent Homes: Earth Closets.

Capital and Philanthropy in London. Miss Coutts.

Venesection: its Abuse formerly, its Neglect at the Present Day.

Intemperance in New England. How shall we treat it? The Data from Official Police Reports.

Brief Memoirs of Louis and some of his Contemporaries in the Parisian School of Medicine of Forty Years ago (with Manuscript Letters from

Mad. Louis, Sir Thomas Watson, etc.). Read before and published by the Boston Society of Medical Observation.

Analysis of a Correspondence on some of the Causes of Consumption.

Intemperance as governed by Cosmic and Social Law. How can we become a Temperate People?

Analysis of the Correspondence on the Use and Abuse of Intoxicating Drinks throughout the Globe; or, Intemperance as seen in the Light of Cosmic Law. (With an Appendix.)

Coggia's Comet: Observations on, while at Chateaugay.

Third Annual Report of the Boston Co-operative Building Company. (In part by Dr. Bowditch.)

Preventive Medicine and the Physician of the Future. Separate print.

State Medicine and Public Hygiene. An Address before the American Medical Association. Separate print.

Memorial of Dr. George Derby. Read before the American Academy of Arts and Sciences.

Report on the Sanitary Condition of the State Prison at Charlestown. (Signed by H. I. Bowditch, Richard Frothingham, and C. F. Folsom.)

Electrolysis in Thoracic Aneurism. Read at a meeting of the Suffolk District Medical Society.

Epidemic among Horses, showing well the Evils of bad Hygienic Influence.

Journey to and Residence at Chateaugay Lake.

Inebriate Asylums or Hospitals.

Sanitary Hints. From the Seventh Report of the Massachusetts State Board of Health. Typhoid Fever, etc.

Closing Remarks at the Meeting of the American Medical Association.

Public Hygiene in America. Centennial Address before an International Medical Congress at Washington, D. C.

Prefatory Remarks to the American Edition of Simon's "Filth Diseases."

Public Hygiene in America, being the Centennial Discourse delivered before the International Medical Congress, Philadelphia, September, 1876, with Extracts from Correspondence from the several States; together with a Digest of American Sanitary Law by Henry G. Pickering, Esq.

Memoir of K. D. P. (Katharine Day Putnam), the Young Lady to whom Lieut. Nathaniel Bowditch was engaged, and Illustrations by Friendly Artistic Hands. 2 vols. 4to.

Empyema, Treatment of, in a Letter to Dr. Holiday.

President's Address before the American Medical Association at its Meeting in Chicago. Journal of Journey to and Doings there.

Memorial Tribute to Dr. L. P. Yandell, of Louisville, Ky.

Journal of the Meeting of the American Medical Association.

Remarks at the Opening of the Boston Medical Library.

Epidemic of Diphtheria at Ferrisburg, Vt.

Journey to Chateaugay and Mount Washington.

Remarks on the Death of Dr. John B. S. Jackson.

Cholera in New York, as described by Dr. Jacob Bigelow.

Prevention of Consumption. A Series of Articles in the "Youth's Companion."

Sanitary Organization of Nations. A Paper read before the Boston Society for Medical Improvement, with a Preface addressed "To all Citizens of Massachusetts who desire that sanitary work may not fail of its highest fulfilment in future years in this Commonwealth."

Laparotomy. Its great Future.

The Three Climates of New England; viz. the Oceanic, the Shore, and the Inland.

The Garrison Mob.

My Letter to Dr. Porcher, of Charleston, S. C., on the Advantages to Mankind of Establishments of Boards of Health by various States.

The Temperance Alliance and Dr. Bowditch.

Medical Education of Women: the present hostile Position of the Harvard Medical School and of the Massachusetts Medical Society. What Remedies therefor can be suggested?

Dr. Elliott of New Orleans proves that the Truth of the Law of Soil Moisture (1862), as discovered by myself and by Dr. Buchanan three years afterwards in England, holds good at New Orleans.

Venesection, its (occasionally) great Value. Remarks on Dr. Dunn's Case.

Letter to the Sanitarian: Views on National and State Sanitation.

Moral Education in Schools; in a Letter to a Teacher, Mr. Fisher of Brooklyn, N. Y., who had asked me to give an opinion on the question.

Two Fatal Cases of Pleuritic Effusion. Would not Thoracentesis have saved Life?

Defence of the National Board of Health from an Insinuation by the Editor of the Boston Daily Advertiser, that, as the Board has been accused of doing little, it had then an opportunity to study Cholera in Mexico.

Brief Remarks made at a Political Primary Meeting on the Duty of every Citizen to attend and take part in such Meetings, and of voting afterwards.

Circular signed, with others, by me, urging the Colored People not to vote for General Butler, on the ground that he would be faithless to them.

Garibaldi. A Letter from the Central Committee of the League of Italian Societies for Cremation, urging that the remains of the hero should be disinterred and cremated, according to the terms of his will.

The Ethical Results of Darwinism. An Essay presented at the Liberal Union Club. "Survival of the Fittest." "Natural Selection."

Woman Suffrage. Remarks before a Committee of the Legislature.

A long Letter to Mr. William H. Thayer on Dr. Beard's assertion that the moral qualities degenerate in old age as the physical and intellectual faculties do.

Tobacco. Evils from the Use of it. A most fruitful source of fees, however, to me it has been during all my professional life. Discussion on Dr. Otis's Paper.

A Letter in Commemoration of Dr. Calvin Ellis.

Memorials of Dr. Calvin Ellis.

The Aspirator in Pleural Effusions. Reply to Dr. Ferguson, of Troy, that the operation "had done more harm than good" in its various applications to different parts of the body.

Letter to Dr. T. W. Richardson of New Orleans.

Invitation from the College of Physicians of Philadelphia to attend its Conversazione, and my reply, in which, owing to ill-health, I declined.

Medical Codes: An Address prepared for the New York State Medical Society.

Treatment of Pulmonary Diseases by means of "Pneumatic Differentiation," by Vincent Y. Bowditch, with Remarks by myself.

Correspondence with Governor Robinson and Hon. F. O. Prince (Candidates for the Governorship), asking them whether if chosen they would advocate a separate and independent Board of Health instead of the combination then existing under the Title of "Board of Health, Lunacy, and Charity."

"Garrison Mob." Semi-centennial Celebration by the Garrison Lyceum.

Pierpont's (Rev. John) Centennial Birthday. Dr. Bartol, "Unitarian Review." My Reminiscences.

The International Medical Congress for 1887.

"Did Ralph Waldo Emerson sympathize with the Abolitionists?" Letters from T. W. Higginson, H. I. B., Rev. S. May, Jr.

Garrison's Reviewers (T. W. Higginson, Leonard Woolsey Bacon, W. J. Potter) and my Estimate of them and of the great Liberator.

Austin Flint, Senior. Funeral at New York. Reflections on the Evils produced upon his Fine Nature by the Code Excitement.

Nathaniel Bowditch, Life of, as published in Horace Mann's Common School Journal, and at his request, after hearing my Address to the Children of the Warren Street Chapel on the Sunday after Father's Death.

Correspondence with Dr. W. W. Potter of Buffalo on his Invitation to attend a Meeting of the New York State Medical Society.

Correspondence (February) with Dr. Collins about going to Providence to attend the Meeting of the Rhode Island Medical Society.

First Copy of my Address before the Rhode Island Medical Society, by Request of the President, on the Topic, "Our Past, Present, and Future Treatment of Homœopathy, Eclecticism, and kindred Delusions."

Modern Thoracentesis and Thoracotomy: a Paper prepared for Pepper's "System of Medicine," and from which Dr. Donaldson has made Copious extracts in the preparation of his Article on "Affections of the Pleura," now to be found in the above work by Dr. Pepper.

Ambroise Paré. Has the Boston Society for Medical Improvement an authentic Portrait of this great Surgeon?

The Past, Present, and Future Treatment of Homœopathy. An Address, June 10, 1886, before the Rhode Island Medical Society. Reprinted from the Transactions of the Society.

Open Air Travel as a Curer and Preventive of Consumption, as seen in the History of a New England Family. Reprinted from the Transactions of the American Climatological Association.

1893. CHARLES F. FOLSOM.

PHILLIPS BROOKS.

Descended on his mother's side from a long line of New England worthies, many of them ministers of the Gospel, PHILLIPS BROOKS was, by virtue of heredity, a scholar and a thinker. The Boston Latin School fitted him for college, Harvard graduated him with honors in 1855, and the Theological Seminary at Alexandria, Virginia, subsequently gave him his training in divinity. After a brief pastorate at the Church of the Advent in Philadelphia, he was placed over the important parish of Holy Trinity in the same city. Here he became famous as a preacher, and when, in 1868, he accepted an invitation to Trinity Church, Boston, his reputation was already a national one. Scarcely had he become wonted to his new cure, when the church in which his pulpit stood was burned to the ground,—a calamity which could scarcely be reckoned wholly such, since it resulted in giving to one of the best architects the country has ever had the opportunity of his lifetime, and to the foremost of contemporary preachers the scope and play to which his extraordinary powers entitled him.

After having held his Boston rectorship with ever increasing acceptance for more than twenty years, Dr. Brooks became, in 1891, Bishop of the Diocese of Massachusetts, but had continued in office scarcely a twelvemonth when he died. Upon the characteristics of Phillips Brooks as preacher and pastor, the writer of this notice would have no occasion to dwell, even if estimates of the man and his work were less numerous than they are. Perhaps in the case of no other American, unless indeed that of some military or political favorite, has the

popular demand for eulogy been more insistent. The Librarian of Harvard College reports the receipt of some twenty-five printed discourses commemorative of him. If to these were to be added the almost countless tributes scattered through the columns of newspapers and the pages of periodicals, both at home and abroad, the aggregate of spoken and written appreciation would be seen to be enormous.

It will therefore better serve the present purpose if the account be taken chiefly of the attitude held by Dr. Brooks towards the particular interests of which the American Academy and other kindred associations are representative. How did this theologian (for theologian in a true sense he was, though preacher first of all) regard natural science, more especially in its bearing upon religion?

Briefly characterized, his attitude towards the scientific movement of the day was one of confident friendliness. While others were discussing possible treaty relations between science and faith, he always seemed to speak and act as if peace were already declared, or rather had never been broken. An ardent theist, and for that reason an assured optimist, he found it impossible to regard with suspicious dread any tidings of discovery that were evidently authentic.

For new treasure, whencesoever brought, space must be found, he argued, and if the present receptacles seemed inadequate, he was for enlarging them. He was impatient of labored attempts accurately to dovetail the postulates of theology with present day theories, cosmic, anthropological, or what not, convinced as he was of the transitory character of all such well meant adjustments. Even the analogies which some popularizers of science are fond of tracing between the natural and the spiritual worlds seemed to possess slight interest for him, and in so far as in his preaching he drew at all upon the resources of "the unseen universe," it was for purposes rather of illustration than of argument that he did so. "I have so many hundred sermons," he was once heard to exclaim, naming a large number, "and I thank God that not one of them deals with the relations of science and religion."

That this reticence was in any measure due to intellectual timidity, no one who had the privilege of knowing Phillips Brooks can for a moment suppose. That it was a wise kind of silence, most of those who are deeply conversant with the conditions of the question will acknowledge.

1893. W. R. HUNTINGTON.

JAMES BICHENO FRANCIS.

James Bicheno Francis was born at Southleigh, Oxfordshire, England, May 18, 1815. He was sent to school at an early age, but when his father was elected Superintendent of Construction of the Porth Cawl South Wales Harbor Works, the lad, anxious for practical work, applied for the position of, and became an assistant to, the engineer. Later he was employed in the construction of the Great Western Canal in Derbyshire.

The works of inland navigation, the improvement of harbors, and the construction of canals, afforded the great opening at that time for engineers. But as a means of transport the canal could only be availed of when a sufficient water supply could be secured, and the speed of transit was not equal to the growing demands of manufacturers and commerce. It was evident from the experience of coal railways, which had been in use for a century, that this system of transport, in its general application throughout a country, was superior to that of canals. With confidence in this decision, enterprising men had undertaken the construction of railways in this country as well as abroad.

Cable traction and the locomotive had been used for some time on coal roads, but their success on long routes had not been established. When the Liverpool and Manchester Railway was undertaken, and till nearly complete, the motor power had not been settled. At last the board of directors decided to refer the matter to a commission of engineers, who reported favorably on the adoption of the locomotive, and drew up a specification for its construction. The report was adopted by the directors, and a prize of £500 was offered for a locomotive to be tested on the railway, complying with the terms of the specification.

The results of the trial of the competitive locomotives, which took place in October, 1829, settled the motor power for railways, and gave an additional impulse to their construction and extension in this country.

Of the practical knowledge of the laying out of railroads and their construction little was of course known anywhere, and especially here. Graduates and students of West Point were detailed, or resigned from the army, to accept positions on railroads; canal engineers of more or less experience and surveyors were drawn from their works at home and abroad, — among others, young Francis, who

landed in New York City, April 15, 1833, consigned with letters of introduction to Phelps, Dodge, & Co.

Confident in himself, he sought Mr. George W. Whistler, then in charge of the construction of the Stonington Railroad, who was so favorably impressed by the appearance of the youth that he sent him at once to Mr. James P. Kirkwood, the resident engineer. When Mr. Whistler, the following year, was called to Lowell by the Proprietors of the Locks and Canals on Merrimac River as their engineer, strongly confirmed in his estimation of the capacity and intelligence of Mr. Francis, he offered him the position of his assistant and that of surveyor of the company.

English locomotives had already been imported and set up by this company; but it was decided to build locomotives larger and of a new type, and for the designing of these especially Mr. Whistler had been called to Lowell. Under his charge successful locomotives were built for the Western and Providence Railroads, and in Mr. Francis he found an able assistant.

In 1837 Mr. Whistler resigned his position as engineer, and was succeeded by Mr. Francis, who married Miss Sarah Brownell, and settled permanently at Lowell.

He had already found that, in his anxiety to get early into practical work, his school life was incomplete, and that he needed a more extended mathematical education, and undertook to obtain this by his own study, with the result that in this branch his education was beyond any college requirements of the time.

As engineer of the company he finished the Boott Canal, and the Boott and the Massachusetts Mills, which completed the laying out as contemplated by the original proprietors.

The Boston Manufacturing Company at Waltham supplied stockholders and mechanics, machinery and mills, for the enterprise at Lowell. There were improvements and extensions, but the type was preserved. Continued success made the management conservative, and it was not till about 1841, after the death of most of the earlier directors of the corporations, that it was thought necessary to investigate what had been done outside by manufacturers in this country and abroad, and a radical change in spinning machinery was adopted; more space was required per pound of product, the canals were of too small capacity, and more economy in the use of water was now of importance. The water-wheels of the best patterns of the times, and giving a large percentage of effect on the single fall, were becoming old and worn, and not adapted to the change expected to be made in the canals.

It was at this time Mr. Francis came in full charge as engineer, and he was the right man for the time and place; eminently conservative, he made up his mind only by thorough study of the conditions and requirements of the subject.

He hunted up the records of the Merrimac River, its high and low water marks, investigated the facilities for storage by reservoirs and flashing, and the condition of the canals, to determine the then available flow, and how much would be obtained by careful watching to prevent loss of head and waste of water. He tested the water-wheels in use, and collected all data pertinent to the improvement of the water power.

In 1845 the Locks and Canals Company sold their machine shop and most of their real estate to outside parties; the balance of the real estate, with the canals and franchise, were transferred to the different manufacturing companies, who became proprietors and members of the corporation under its old title, with interests in proportion to the number of mill powers originally purchased by them.

Although Mr. Francis had but little to do with the running of the machine shop and the construction of machinery, yet with the advice in new constructions and care and division of a large real estate, a great deal of his time was taken up. With the change incident to the sale, he became agent also of the company, and had opportunity and greater support in carrying out changes for the improvement of the water power which had long been recognized as of vital importance.

The interest of the new proprietors of the old company was now essentially a Lowell interest, and a mutual one, to secure as large and as permanent a water power as possible. Mr. Francis, by his experience and studies, was well posted in the potentialities of the Merrimac River at Lowell. He was personally acquainted and intimate with the board of directors, who had implicit confidence in his integrity and capacity.

Although Mr. Francis well knew what would be required for the improvements of the water power, and what in the end would be his complete design, yet in his recommendations he was economical and progressive, following out the line he had laid out, and securing those advantages which were first needed and most readily obtainable.

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In 1846, the Locks and Canals Company together with the Essex Company at Lawrence organized the Lake Company, and secured the control of the outlet of Lake Winnipiseogee, with other ponds and lakes in the vicinity. The object of the purchase was to improve the storage capacity of the lake by raising the water in it, and by pro-

popular demand for eulogy been more insistent. The Librarian of Harvard College reports the receipt of some twenty-five printed discourses commemorative of him. If to these were to be added the almost countless tributes scattered through the columns of newspapers and the pages of periodicals, both at home and abroad, the aggregate of spoken and written appreciation would be seen to be enormous.

It will therefore better serve the present purpose if the account be taken chiefly of the attitude held by Dr. Brooks towards the particular interests of which the American Academy and other kindred associations are representative. How did this theologian (for theologian in a true sense he was, though preacher first of all) regard natural science, more especially in its bearing upon religion?

Briefly characterized, his attitude towards the scientific movement of the day was one of confident friendliness. While others were discussing possible treaty relations between science and faith, he always seemed to speak and act as if peace were already declared, or rather had never been broken. An ardent theist, and for that reason an assured optimist, he found it impossible to regard with suspicious dread any tidings of discovery that were evidently authentic.

For new treasure, whencesoever brought, space must be found, he argued, and if the present receptacles seemed inadequate, he was for enlarging them. He was impatient of labored attempts accurately to dovetail the postulates of theology with present day theories, cosmic, anthropological, or what not, convinced as he was of the transitory character of all such well meant adjustments. Even the analogies which some popularizers of science are fond of tracing between the natural and the spiritual worlds seemed to possess slight interest for him, and in so far as in his preaching he drew at all upon the resources of "the unseen universe," it was for purposes rather of illustration than of argument that he did so. "I have so many hundred sermons," he was once heard to exclaim, naming a large number, "and I thank God that not one of them deals with the relations of science and religion."

That this reticence was in any measure due to intellectual timidity, no one who had the privilege of knowing Phillips Brooks can for a moment suppose. That it was a wise kind of silence, most of those who are deeply conversant with the conditions of the question will acknowledge.

1893. W. R. Huntington.

JAMES BICHENO FRANCIS.

JAMES BICHENO FRANCIS was born at Southleigh, Oxfordshire, England, May 18, 1815. He was sent to school at an early age, but when his father was elected Superintendent of Construction of the Porth Cawl South Wales Harbor Works, the lad, anxious for practical work, applied for the position of, and became an assistant to, the engineer. Later he was employed in the construction of the Great Western Canal in Derbyshire.

The works of inland navigation, the improvement of harbors, and the construction of canals, afforded the great opening at that time for engineers. But as a means of transport the canal could only be availed of when a sufficient water supply could be secured, and the speed of transit was not equal to the growing demands of manufacturers and commerce. It was evident from the experience of coal railways, which had been in use for a century, that this system of transport, in its general application throughout a country, was superior to that of canals. With confidence in this decision, enterprising men had undertaken the construction of railways in this country as well as abroad.

Cable traction and the locomotive had been used for some time on coal roads, but their success on long routes had not been established. When the Liverpool and Manchester Railway was undertaken, and till nearly complete, the motor power had not been settled. At last the board of directors decided to refer the matter to a commission of engineers, who reported favorably on the adoption of the locomotive, and drew up a specification for its construction. The report was adopted by the directors, and a prize of £500 was offered for a locomotive to be tested on the railway, complying with the terms of the specification.

The results of the trial of the competitive locomotives, which took place in October, 1829, settled the motor power for railways, and gave an additional impulse to their construction and extension in this country.

Of the practical knowledge of the laying out of railroads and their construction little was of course known anywhere, and especially here. Graduates and students of West Point were detailed, or resigned from the army, to accept positions on railroads; canal engineers of more or less experience and surveyors were drawn from their works at home and abroad, — among others, young Francis, who

landed in New York City, April 15, 1833, consigned with letters of introduction to Phelps, Dodge, & Co.

Confident in himself, he sought Mr. George W. Whistler, then in charge of the construction of the Stonington Railroad, who was so favorably impressed by the appearance of the youth that he sent him at once to Mr. James P. Kirkwood, the resident engineer. When Mr. Whistler, the following year, was called to Lowell by the Proprietors of the Locks and Canals on Merrimac River as their engineer, strongly confirmed in his estimation of the capacity and intelligence of Mr. Francis, he offered him the position of his assistant and that of surveyor of the company.

English locomotives had already been imported and set up by this company; but it was decided to build locomotives larger and of a new type, and for the designing of these especially Mr. Whistler had been called to Lowell. Under his charge successful locomotives were built for the Western and Providence Railroads, and in Mr. Francis he found an able assistant.

In 1837 Mr. Whistler resigned his position as engineer, and was succeeded by Mr. Francis, who married Miss Sarah Brownell, and settled permanently at Lowell.

He had already found that, in his anxiety to get early into practical work, his school life was incomplete, and that he needed a more extended mathematical education, and undertook to obtain this by his own study, with the result that in this branch his education was beyond any college requirements of the time.

As engineer of the company he finished the Boott Canal, and the Boott and the Massachusetts Mills, which completed the laying out as contemplated by the original proprietors.

The Boston Manufacturing Company at Waltham supplied stockholders and mechanics, machinery and mills, for the enterprise at Lowell. There were improvements and extensions, but the type was preserved. Continued success made the management conservative, and it was not till about 1841, after the death of most of the earlier directors of the corporations, that it was thought necessary to investigate what had been done outside by manufacturers in this country and abroad, and a radical change in spinning machinery was adopted; more space was required per pound of product, the canals were of too small capacity, and more economy in the use of water was now of importance. The water-wheels of the best patterns of the times, and giving a large percentage of effect on the single fall, were becoming old and worn, and not adapted to the change expected to be made in the canals.

It was at this time Mr. Francis came in full charge as engineer, and he was the right man for the time and place; eminently conservative, he made up his mind only by thorough study of the conditions and requirements of the subject.

He hunted up the records of the Merrimac River, its high and low water marks, investigated the facilities for storage by reservoirs and flashing, and the condition of the canals, to determine the then available flow, and how much would be obtained by careful watching to prevent loss of head and waste of water. He tested the water-wheels in use, and collected all data pertinent to the improvement of the water power.

In 1845 the Locks and Canals Company sold their machine shop and most of their real estate to outside parties; the balance of the real estate, with the canals and franchise, were transferred to the different manufacturing companies, who became proprietors and members of the corporation under its old title, with interests in proportion to the number of mill powers originally purchased by them.

Although Mr. Francis had but little to do with the running of the machine shop and the construction of machinery, yet with the advice in new constructions and care and division of a large real estate, a great deal of his time was taken up. With the change incident to the sale, he became agent also of the company, and had opportunity and greater support in carrying out changes for the improvement of the water power which had long been recognized as of vital importance.

The interest of the new proprietors of the old company was now essentially a Lowell interest, and a mutual one, to secure as large and as permanent a water power as possible. Mr. Francis, by his experience and studies, was well posted in the potentialities of the Merrimac River at Lowell. He was personally acquainted and intimate with the board of directors, who had implicit confidence in his integrity and capacity.

Although Mr. Francis well knew what would be required for the improvements of the water power, and what in the end would be his complete design, yet in his recommendations he was economical and progressive, following out the line he had laid out, and securing those advantages which were first needed and most readily obtainable.

In 1846, the Locks and Canals Company together with the Essex Company at Lawrence organized the Lake Company, and secured the control of the outlet of Lake Winnipiseogee, with other ponds and lakes in the vicinity. The object of the purchase was to improve the storage capacity of the lake by raising the water in it, and by pro-

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viding suitable sluiceways for drawing the water out in dry seasons, to be used for power at Lowell and Lawrence when the Merrimac River was low. This advantage was secured in part at once, and appliances were soon constructed for regulation, by which the water could be retained or supplied at need.

This arrangement was continued till 1889, when the Lake Company was transferred to a syndicate of New Hampshire manufacturers, who naturally were more in accord with their own Legislature, with relief from taxation of the Massachusetts proprietors and little change in the conservative use of the water; whilst now slight irregularities of flow could be readily met by the improved means of pondage and distribution of water at Lowell and Lawrence.

Under the new proprietorship of the Locks and Canals Company it was necessary that all the mills should, as near as possible, have the proportion of water to which they were entitled. To effect this Mr. Francis designed and constructed the Northern Canal, a very large and independent feeder, with branches to all the other canals. This work was begun and finished with thoroughness and economy, and still remains, with its massive walls and gates, its ample dimensions and permanency of construction, as a worthy monument to its engineer.

As it was of great advantage to be able to shut and open the head gates with but little manual labor, this was effected by a turbine wheel moving nuts on vertical screws attached to the gates. With the construction of the fire service reservoir, ample power was readily available from the mains for hydraulic lifts, which are now applied to other head gates.

The head gates of the old canal consisted of the usual slide gates and a lock for the purpose of navigation. From the records of high water of the last century, Mr. Francis was satisfied that the coping of these locks was not high enough to restrain a like freshet, and that it would flow over, destroy the work, and sweep out the business part of the city of Lowell. He therefore raised the walls of the lock, and constructed grooves in them from its floor to a height well above the freshet mark, and in the grooves he hung a solid timber portcullis or slide gate not interfering with navigation. Two years after its completion (1850) Mr. Francis's expected freshet came, the flood was fast approaching the danger height at the coping, the iron strap was cut, and the gate fell; and although the water continued to rise even above the old mark, the city of Lowell was safe. The gate has now been raised and set again.

Although Mr. Francis recognized the possibility of such a freshet, and made his designs and personally carried them out to prevent disaster, it was not then considered necessary by most of the citizens; yet it was his nature not to undertake any risks; he studied up well the problem presented and omitted no known factors in the solution.

The repairs, renewal, and maintenance of the canals, and the prevention of water waste, was a constant source of care. A new dam was built on the site of the old one, rights of higher flashing secured and consequent pondage, and a portion of Hunt's Fall was removed for the increase of the fall and the relief of the mills on the river's level.

With the organization of a mutual fire insurance by the mill-owners Mr. Francis became its head, to build a fire-service reservoir with the full plant. Turbines, engines, and pumps, mains and hydrants, and the mill appliances of pipes, valves, sprinklers were constructed and placed under his direction and inspection, and maintained under his rules and regulations; and so well were these kept that the loss by fire was less than one tenth of one per cent.

For the preservation of the bridges and other wooden structures, of which there were many belonging to the company, he introduced the Kyanizing and Burnettizing processes, which are still continued for the use of the Lowell companies and others, and form a profitable industry.

In 1844, Mr. Uriah A. Boyden constructed his first turbine for the Appleton Company, which proved successful. Mr. Francis assisted at the test, as he did also at that of two other wheels for the same company in 1848, when the maximum effect was determined and paid for at the rate of 88 per cent of the water expended. Mr. Boyden continued to build wheels, testing the same often with Mr. Francis's assistance and always with his cognizance of the changes of construction and results. Impressed with the great advantage of the adoption of this wheel at Lowell, at his recommendation the manufacturing companies purchased of Mr. Boyden the rights to his improvements relating to turbines and other hydraulic motors. After that, it devolved on Mr. Francis to design and superintend the construction of such turbines as might be wanted for their mills. To this work he brought his accustomed industry, assisted by Mr. Boyden's drawings, but more by his own comparison and analysis of the most successful designs.

This analysis of the working of turbines was continued by testing them as they were applied to the different mills to determine the quantities of water used, the percentage of effect obtained, and the

forms of construction most durable and convenient of application. Records of all the data necessary for this were carefully taken and kept, and selections made from them by Mr. Francis, and published in 1855 under the title of "Lowell Hydraulic Experiments." In addition to the turbines there were some records of experiments on the flow of water through rectangular channels, which was important to the different manufacturing establishments to enable them to secure their respective rights.

It was necessary that the gaugings should be frequent, that they should involve no stoppage of any works, nor impairment of the power, and that it should be made under the normal conditions of working. This was so secured by rectangular channels and the use of deep tube floats.

The practical application of the system and the results, together with some experiments on submerged orifices and diverging tubes, were given in a second edition of the "Hydraulic Experiments," published in 1868.

By this work the reputation of Mr. Francis was extended beyond this country. Here he was well known not only as an engineer of the most important water power in the United States, to the success of which he had contributed so much, but by his extensive consulting and expert practice, (which continued to increase till his health was impaired,) and his many contributions to the Journal of the Franklin Institute, the Transactions of the Society of Civil Engineers, and published reports. Mr. Francis was a man of method, and studied carefully not only matters of engineering, but all the numerous subjects on which he was consulted outside of his profession. Of most of these, the data obtained are preserved with his calculations; and so varied and important are they that it has been thought expedient to file and index them, which has been done by his son and successor, Colonel James Francis, and they are now kept in the office of the Proprietors of Locks and Canals, open to all who have an interest in these subjects.

His friend, the eminent engineer Uriah A. Boyden, appointed Mr. Francis and Hon. William G. Russell trustees of his estate, inventoried at $180,000, for the establishment and maintenance of a mountain peak observatory or to aid in the same. In investigating observatories Mr. Francis visited the principal ones in the United States, taking them in the line of what he called his vacations, and with but little charge to the estate. Through economies of administration the trustees turned over to Harvard College $232,560, to be used by the

Cambridge Observatory for the establishment of an observatory at Arequipa, Peru.

It was Mr. Francis's fortune to be known and appreciated; he was one of the earliest members of the American Society of Civil Engineers, its President, and an Honorary Member; President of the Boston Society of Civil Engineers; member of the American Philosophical Society of Philadelphia, of the Boston Society of Natural History, of the Winchester Historical Society, of the Arkwright Club, of the Trinity Historical Society, Dallas, Texas, and of the American Society of Irrigation Engineers, of Salt Lake City, Utah. He received the honorary degree of Master of Arts from Dartmouth College in 1851, and from Harvard College in 1858. He was a member of the Corporation of the Massachusetts Institute of Technology; President of the Stony Brook Railroad for twenty years; Director of the Railroad Bank for thirty-two years, and of the Lowell Gas Light Company for forty-three years.

Mr. Francis was elected a Fellow of this Academy on the 13th of November, 1844, and served as a member of the Rumford Committee from 1868 to 1878. He contributed to the sixth volume of our Proceedings an important paper, "On the Strength of Cast-iron Pillars," afterwards reprinted and published as a separate volume by D. Van Nostrand.

Never desirous of political office, as a matter of duty he served one term in the Legislature, longer in the City Government and on the School Committee, as a Director of the City Library, and as Commissioner for the erection of the new City Hall.

Mr. Francis resigned the office of agent and engineer of the Proprietors of Locks and Canals on Merrimac River, January 1, 1883, and was appointed consulting engineer, which position he held at the time of his death, September 18, 1892. Although affected for some time with a complaint dangerous to any man of his years, he continued almost to the day of his death his interest in his usual pursuits, and died, leaving a widow, four children, and grandchildren.

Mr. Francis, in the many positions to which he was called with varied duties, showed himself an admirable executive and administrative officer, and in his published works and reports a close and careful investigator, suggestive in his methods, and of good judgment. Often chosen from his established integrity referee and commissioner, not only in the line of his profession, but outside, his decisions were without bias. As leading hydraulic expert of this country and often retained in suits, he never considered himself the attorney of his client, but

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gave his evidence honorably, agreeably to the facts and scientific precedents. In this his example is worthy of imitation, and suggestive as to whether it would not be an improvement in the present practice if like men should be retained by the court rather than by the contestants.

In private life Mr. Francis was honest, sympathetic, neighborly, not hasty in forming or giving opinions, but always consistent and decided, liberal, a good citizen and Christian gentleman, contributing largely to the honor and welfare of the city, whose memory will be long and gratefully preserved by its inhabitants.

1893. W. E. Worthen.

EBEN NORTON HORSFORD.

Eben Norton Horsford was born on July 27, 1818, at Moscow, Livingston County, New York. His father, Jerediah Horsford, sprung from an old New England stock, came from Charlotte, Vermont, and settled at Moscow as a missionary to the Seneca Indians. His mother, whose maiden name was Charity Maria Norton, came from Goshen, Connecticut, and traced her descent from Thomas Norton of Guildford and John Mason, the famous captain in the Pequot war. She was a woman of strong intellectual tastes, and remarkable for her public spirit, shown by the fact that, after reading her books, she made of them a sort of free circulating library for the benefit of her neighbors in what was then a wild and primitive region.

Amid such surroundings at home it was not strange that the boy grew up with strong scholarly tastes, and was known to his playmates as a marvel of general information. It is interesting to note that a favorite amusement was collecting the fossils which abounded on his father's farm, as this recreation of his boyhood undoubtedly turned his thoughts toward the natural sciences, to which so large a part of his manhood was devoted, while at the same time his early association with the Seneca Indians, who flocked to his father's house in large numbers, familiarized him with Indian words and pronunciation, and thus paved the way for the philological and archæological studies of his older years.

In his education away from home, the most important influence was Mrs. Jared Wilson, the wife of the teacher of the Livingston County School, where he passed the years from thirteen to sixteen, his earlier education having taken place in the schools of the district.

Mrs. Wilson was a remarkable woman, and did much toward building up his character on the broad foundations laid by his mother.

From the Livingston County School he went to the Rensselaer Polytechnic Institute of Troy, New York, from which he graduated as a civil engineer in 1837. While studying at the Rensselaer Institute he spent his vacations in earning money toward his support, at first by teaching at Leroy, and later by work on the surveys for the New York and Erie, and the Rochester and Auburn Railroads.

After his graduation he obtained for a time congenial employment on the Geological Survey of the State of New York, under Professor James Hall, and in 1840 was appointed Professor of Mathematics and Natural Sciences in the Albany Female Academy, a position which he held for four years. During this time he took up the study of Daguerre's photographic process with Morse, the inventor of the telegraph, and this work attracted the attention of the scientific world to him, and led to his delivering a course of lectures on chemistry at Newark College in Delaware in 1843, and another in 1844, after he had left the Albany Academy. This period at Albany was of great importance in the formation of his character; Hall and Morse fostered his taste for scientific research and impressed upon him careful and accurate methods of work; the Reverend Dr. William Sprague had a strong influence on his general development; and at the Female Academy he met Mary L'Hommedieu Gardiner, who afterward (in 1847) became his wife.

So far as his future was concerned, the most important result of his growing reputation was an invitation from Professor Webster to visit him in Cambridge, when he urged Horsford to go abroad and study, — advice which was followed in December, 1844. Arrived in Germany he turned his steps toward Giessen, at that time the goal of all chemical students, where Liebig had recently introduced the modern method of teaching chemistry in the laboratory. Here he spent two happy profitable years in the society of such men as Hofmann (whose desk was next his), Williamson, Fresenius, Will, and many others who afterward became famous in the science, — a chemical family over which Liebig exercised a fatherly care. At the end of this time Liebig, with whom he was a great favorite, urged him to take the degree of Doctor of Philosophy. This he refused to do, because he was living on borrowed money, and thought it not right to involve himself further in debt, even by the slight amount of the fee for the degree. Liebig induced the University to offer to remit the fee, a great honor when the tenacity with which Universities

cling to their fees is remembered; but Horsford, from honorable though exaggerated scruples, refused to accept this favor, and returned to America, without a degree it is true, but with his mind broadened by contact with such different surroundings and intercourse with men of the first intellectual ability, his chemical knowledge pushed even to organic chemistry, at that time the very frontier of the science, and bearing as proofs of his acquisitions a paper on glycocoll and a strong recommendation from Liebig. These at once caused his election, at the instance of Professor Webster, to the "Rumford Professorship of the Application of Science to the Useful Arts" in Harvard University, and his first duty in this position was to organize the laboratory of the newly founded Lawrence Scientific School after the plan of that at Giessen. He addressed himself to this task with the energy which was so large a part of his character; the laboratory opened most successfully, and flourished under his management for sixteen years, during which time many chemists of distinction were educated there. As a teacher he was remarkably clear and suggestive, and with his sanguine, enthusiastic temperament was always urging his students along the new lines of work which he had proposed to them.

Among the papers published by him at this period of his life only a few of the most striking can be mentioned. Such are an extended research on the action of mercury on various metals, a theoretical paper on the relation between the properties of the metals of the alkaline earths and their atomic weights, and, more important than these, some other discoveries, which are at the same time more characteristic of the man because they were undertaken to benefit mankind directly, rather than to throw light on the more abstruse portions of the science. One of these was a paper on the action of water on lead pipes, which contained some of the results of an exhaustive investigation into the best material for the water-pipes of Boston at the time of the introduction of Cochituate water. This work occupied him for many years, but, as he considered it a public service, he refused the very ample compensation offered him by the city of Boston, although at the time decidedly in need of money. The city accordingly presented him with a handsome service of plate. The other inventions of this class do not appear in the list of his scientific papers, but include his most valuable work. Such are his fundamental improvements in the art of making cider, at that time a large industry in New England, and the invention of condensed milk. The latter he worked out for use in Dr. Kane's Arctic Expedition, and afterward gave the process to one of his assistants named Hoffmann, who sold

it to Borden, so that Horsford himself got no advantage from it; but his merit as the inventor of this most important preparation was recognized at the Vienna Exhibition of 1873 by a diploma of honor. Another of these important inventions was the phosphatic yeast-powder, the object of which was to return to the bread the phosphates lost in bolting the flour, and which, as is well known, form such an essential constituent of the food of animals. In 1856 he undertook the manufacture of this yeast-powder, founding the Rumford Chemical Works for this purpose, and after he had secured his rights by a lawsuit which dragged along during seven wearisome years, and overcome the great difficulties inseparable from the establishment of a new process on a commercial scale, he made it a great success, which was enhanced later by the use of the acid portion of the yeast-powder as a medicine and beverage under the name of acid phosphate. It is pleasant to see that this work, which was undertaken primarily for the good of mankind by improving the quality of our principal food, should have brought him such a substantial reward. The demands of this business, however, became so great, that, in 1863, he was obliged to resign the Rumford Professorship to devote himself entirely to its management. After his retirement from his professorship he continued to live in Cambridge until his death, as it had become endeared to him by his long residence and the brilliant society in which it then rejoiced.

In addition to the useful inventions already mentioned, several other pieces of public service date from the period of his professorship, especially during the war. He was devotedly patriotic, as was to be expected from the son of a woman whose house was one of the stations on the "Underground Railroad" for the escape of fugitive slaves, and rendered great service by contriving a plan for the defence of Boston Harbor, having been appointed on a commission for this purpose by Governor Andrew, and by devising a marvellously compact and light marching-ration of compressed beef and parched wheat grits, of which half a million were prepared by the government at the instance of General Grant. A description of this ration was published in pamphlet form.

In 1847 he married Mary L'Hommedieu Gardiner, who died in 1855; and in 1857 he married her sister, Phœbe Dayton Gardiner, who survives him. These ladies were the daughters of the Hon. Samuel Smith Gardiner, of Shelter Island, New York, and after his death Professor Horsford and his family came into exclusive possession of his very large estate there by the purchase of the interest of

the other heirs. After this he usually spent his summers on Shelter Island, and these were the parts of the year which he enjoyed most; the scenery of the island is beautiful and restful, the climate delicious, and the old manor-house, with the estate, which has been in the family from the time of the Indians, full of most interesting associations. He soon became interested in studying the antiquities of the place and the family, and erected monuments to the Quakers who were sheltered here from Puritan persecution. Afterward these antiquarian studies took a broader field from a chance reference let fall by one of his guests to the legendary Norumbega, and furnished him with an engrossing and congenial occupation for the later years of his life. The results of his researches were published in a series of costly monographs, illustrated with heliotypes and reproductions of ancient maps, of which he accumulated an almost unrivalled collection.

The following are the most important of his discoveries in this field: the identification of Salem as the place of the landfall of John Cabot; the discovery of the fort of Norumbega on the Charles River, and of the city of the same name in Watertown, Massachusetts, including the finding of many curious remains; the Norsemen in America, and the identification of the site of the house of Leif Erikson in Cambridge by the determination of the approximate latitude, and the recognition of the topographic features described in the saga, confirmed later by the discovery of hearths and other portions of an ancient house; finally, the origin of the name America, which, as well as many other names in this country, he derived from Eric, the father of Leif. These conclusions of his met with much opposition, as was to be expected, but they brought him an invitation to take part in the scientific proceedings of the Society of Americanisti in Spain in commemoration of the discovery of America by Columbus, to which he responded by the paper on the name of America mentioned above, and also led to his creation by the King of Denmark a Knight Commander of the third grade of the Order of Dannebrog in October, 1892, an honor which has found few parallels in America. Among his services to archæological and philological science should not be forgotten his publication of the Dictionary of the Iroquois and Algonquin Languages, written by Zeisberger, and for many years preserved in manuscript in the Library of Harvard College.

In 1873 he revisited Europe as United States Commissioner to the Vienna Exhibition, where he occupied a commanding position on the jury for food products. He afterward published the results of some

of his observations made at this time in an able pamphlet on Vienna Bread. One of the great pleasures of this visit to Europe consisted in renewing the old friendships formed in Giessen; but the best of these was not to be renewed, as Liebig, his chemical father, died while he was on his voyage from America. In 1880 he again crossed the ocean, this time to visit Norway, and again in 1890, when he took a course of the waters at Carlsbad. In the mean time he had not neglected the Western Hemisphere, as he made two journeys to California, in the second one visiting Mexico also, and in 1887 took a voyage to Demerara and the Windward Islands.

In 1876 he served as a juror at the Centennial Exhibition in Philadelphia, and he was twice, with an interval of thirty years between the appointments, an Examiner of the Mint. He was elected a Resident Fellow of our Academy on May 25, 1847.

He delivered numerous popular lectures, among others the first course at the Lowell Institute; and of his addresses should be especially mentioned that at the Morse Memorial in 1872, afterward published in pamphlet form, and the oration at the unveiling of the statue of Leif Erikson in Boston in 1887.

The wealth which came to him as a result of his ability in manufacturing chemistry was freely used in charity, both public and private. Of Wellesley College he was a frequent and liberal benefactor, showing in his gifts a wisdom which does not always distinguish those who give money to colleges. First among these should be placed his endowment of the library, providing for its administration, as well as more than doubling the number of books. Among these additions should be especially mentioned the valuable Powell collection on comparative philology. The Professors also are indebted to him for the establishment of a year of rest in every seven, and the foundation of a pension fund. Among his other gifts are a fund for scientific apparatus, an electric light plant, and an ozone apparatus for purifying the air of the halls, which has proved very successful in this, so far as I am aware, its first use on a large scale. These, however, form but a small part of what he gave the College, since he was continually on the watch to satisfy its needs as they arose, not only to add to its efficiency, but to promote the health and comfort of both professors and students; and quite as valuable as his gifts in money was the sympathetic interest with which, as President of the Board of Visitors from its foundation, he watched over the interests of the College, and fostered its growth.

This useful and happy life came to an end, January 1, 1893, when,

after only little more than twelve hours of sickness, he died of heart disease.

His most prominent personal characteristic was a genial gayety, which, with his cordial, exuberant hospitality, was simply the overflowing of his large, warm heart; this endeared him to his hosts of friends, among whom were numbered many of the brilliant poets and scientific men who adorned Cambridge during the time of his service as Rumford Professor, and such others as Ole Bull, Ericsson, and Henry. It also manifested itself in the affectionate care with which he treated the operatives of the Rumford Chemical Works, more as if they were his children than his paid laborers. Nowhere were these beautiful traits in his character more delightfully manifested than in his beloved Sylvester Manor at Shelter Island, where he was in his element, dwelling on the familiar but ever fresh beauties of the scenery, showing his visitors the latest improvements, or delighting them with learned and interesting accounts of the antiquities of the island, or his own more extended archæological researches. In these researches he showed the singular ingenuity of mind, the dogged persistency in clinging to a problem until he had mastered its minutest details, the unconquerable enthusiasm, and the honesty of purpose which were his leading characteristics, and to which his great success in the worlds of science aud business was due. In reviewing his life, his successes, great as they were, are not the most striking things. These are rather his extraordinary public spirit and his high sense of honor; and it is pleasant to realize that he achieved to a remarkable degree the main object in his career, both as a scientific man and as a citizen, — the help and improvement of his fellow creatures.

1893. CHARLES L. JACKSON.

WILLIAM RAYMOND LEE.

COLONEL WILLIAM RAYMOND LEE, whose death on the 26th of December, 1891, attracted considerable attention at the time, belonged to the Marblehead or Revolutionary Lees. His grandfather, whose name he bore, was in the Revolutionary War the colonel of a Marblehead regiment. From him Colonel Lee derived his right to membership in the Cincinnati. Another ancestor, Jeremiah Lee, was prominent in many ways in the Revolutionary struggle.

William Raymond Lee was born in 1807. He was educated at West Point, where he was a member of the class of 1829. He

remained there for nearly the prescribed term, but left before receiving his commission. He followed the calling of a civil engineer, and was for many years the Superintendent of the Boston and Providence Railroad.

On the breaking out of the Civil War, Lee promptly offered his services to Governor Andrew. He had never been in the army, but he had had a military education; and although he was far beyond the usual age for active duty in the field, he gallantly took his place as colonel of a regiment. This regiment, the Twentieth Massachusetts, was his creation. He selected the field and staff officers, and most of those of the line. He gave it its standard of military duty. He inspired his command with his own high spirit of devotion and steadfastness. Well did the regiment repay him by its magnificent behavior on many a bloody field.

Colonel Lee was taken prisoner at the unfortunate affair of Ball's Bluff, and was one of the hostages selected by the Confederate government to receive the treatment which was awarded to Confederate privateersmen by the mistaken policy pursued by Federal authorities at the outset of the war. His sufferings were severe, and for a time even endangered his life. Fortunately, this exceptional treatment did not last long, and early in 1862 he was exchanged. He led his regiment throughout the Peninsular campaign; he was at Yorktown, Fair Oaks, Savage's Station, Glendale, and Malvern Hill. Then the Army of the Potomac was removed from the Peninsula. In the bloody battle of Antietam, the regiment, still under Lee, suffered heavy loss, but fully sustained its reputation. But the strain of field service proved too much for its commanding officer. Few men at the age of fifty-five can long continue to bear the hardships and labors inseparable from active service in the line. After a vain struggle with increasing infirmity, Colonel Lee was obliged to resign.

His military life was brief, but distinguished. It was also eminently useful. His spirit of unreserved devotion to the cause, his noble example in bravely and uncomplainingly enduring all the hardships of a soldier's life, his strict, high standard of military honor and duty, inspired his regiment with the like high principles and sentiments; while his great kindliness of heart, his unselfishness, and his uniform considerateness for the rights and feelings of his officers and men made him beloved and re-

spected by his entire command. For his gallant and meritorious services he received the brevet rank of Brigadier General of Volunteers.

After the war he lived in comparative retirement. His infirmities increased; he was not able to play any part in active life. But he was not forgotten. His neighbors and friends continued to seek his counsel. The officers of his old regiment sought him out, and on every fitting occasion evinced the regard and honor in which they held him. It was a touching sight to see at his funeral some fifty or more of the enlisted men of the Twentieth, veterans of Ball's Bluff, Antietam, Fredericksburg, Gettysburg, and the Wilderness, mustering, with their badges of mourning, to pay to their gallant leader the last tribute of respect and affection. But not only will his memory be cherished by those who knew him; his place among the Massachusetts colonels will always be a high one. The service he rendered to the State in the crisis of the Civil War will always be fully and gratefully remembered.

Colonel Lee was married in 1842 to Helen Maria Amory, daughter of the late Thomas Amory, Esq., of Roxbury. She survived him about two years. His eldest son, Arthur Tracy Lee, was educated at West Point, and died in 1870, a Lieutenant in the Fifth Artillery. Another son, Robert Ives Lee, and a daughter, Elizabeth Amory, the wife of Colonel O. H. Ernst of the Army, survive him.

1893. JOHN C. ROPES.

LEWIS MILLS NORTON.

DR. LEWIS MILLS NORTON, a Resident Fellow of this Academy and a member of the Council of the American Chemical Society, died, after a short illness, on April 26, 1893. He was born in Athol, Massachusetts, December 26, 1855, and was the only son of the Rev. John Foote Norton and Ann Maria Mann. His early youth was spent in Athol, Wellesley, and Natick, Massachusetts, and in Fitzwilliam and Keene, New Hampshire.

He was an earnest student of chemistry at the Institute of Technology for three years, from 1872 to 1875, when he was appointed Assistant in Analytical Chemistry, in which capacity he served for two years. In May, 1877, he went to Europe, and continued his chemical studies at Berlin, Paris, and Göttingen until August, 1879, and

received his degree of Doctor of Philosophy from the University of Göttingen.

On his return to this country he entered the Amoskeag Manufacturing Company of Manchester, New Hampshire, as chemist, where he gained valuable practical experience which strongly influenced his subsequent career as a teacher of industrial chemistry.

In 1881 he returned to the Massachusetts Institute of Technology as Instructor in General Chemistry. In 1883 he was appointed Assistant Professor in Organic Chemistry, and in 1885, Associate Professor in Organic and Industrial Chemistry. The combined duties of these two growing departments proved too much for one man to carry, and Dr. Norton gave up the systematic instruction in organic chemistry at the end of the Institute year in 1891, and after that time devoted his entire thought and strength to the subject of industrial chemistry, in which he was deeply interested.

In 1888, the Faculty of the Institute of Technology, upon the scheme presented by Dr. Norton, founded the course in chemical engineering. That a course of study was needed which should add to a thorough training in mechanical engineering a thorough knowledge of general, theoretical, and applied chemistry was at once evident by the number of students of fine scholarship who entered the new course. Under Dr. Norton's fostering care the course in chemical engineering increased in numbers and efficiency. He gave it his best thought and effort, and happily saw before his death the course established on a firm foundation.

The professional papers contributed by Dr. Norton to various scientific and technical journals were very numerous, and include a wide range of subjects. The following list contains his more important papers: —

1878. (With J. F. Elliott.) Ueber die Einwirkung von Schwefelammonium auf Pikramid. Ber. d. chem. Gesell., 1878, p. 327.

1878. (With A. Michael.) Ueber die Einwirkung des Chlorjods auf Aromatische Amine. Ibid., p. 107.

1879. Ueber die Einwirkung von Chlorjod auf die Amine der Benzolreihe. (Inaugural Dissertation.) Pamph. 8vo, pp. 36. Göttingen.

1879. (With A. Michael.) On the Action of Iodine Monochloride upon Aromatic Amines. Am. Chem. Jour., I. 255–267.

1880. (With same.) On α- and β-Monobromcrotonic Acids. Ibid., II. 11–19.

1884. (With C. O. Prescott.) Continuous Etherification. Ibid., VI. 241–246.

1884. (With W. R. Nichols.) Laboratory Experiments in General Chemistry, compiled for the Use of Students of the Massachusetts Institute of Technology. Pamph. 12mo, pp. 58 and viii. Boston, 1884, 1885, 1886, 1887.

1885. Coal Tar, and the Colors derived from it. Proc. Soc. Arts, M. I. T., 1884–85, pp. 29–33.

1885. Minor (Chemical) Investigations. Am. Chem. Jour., VII. 114–120.

1885. (With A. W. Allen.) Ueber die Einwirkung der verdünnten Salpetersäure auf die Anilide. Ber. d. chem. Gesell., XVIII. 1995–1999..

1886. (With C. W. Andrews.) The Action of Heat on Liquid Paraffins. Am. Chem. Jour., VIII. 1–9.

1886. (With A. A. Noyes.) On the Action of Heat upon Ethylene. Ibid., VIII. 362.

1887. (With H. J. Williams.) On the Action of Bromine on Isobutylene. Ibid., IX. 87.

1887. (With C. B. Kendall.) Preparation of Alizarine Assistant and its Action in Turkey-Red Dyeing. Textile Record, 1887, p. 227.

1887. (With W. D. Livermore.) Ueber die Einwirkung von verdünnter Salpetersäure auf Substituirte Amidoverbindungen. Ber. d. chem. Gesell., XX. 2268.

1887. (With H. A. Richardson.) Ueber Leinölsaure. Ibid., XX. 2735.

1887–88. The Dyeing of Cotton Yarn. Textile Record. A Series of Articles from June, 1887, to March, 1888.

1888. (With H. A. Richardson.) On the Fatty Acids of the Drying Oils. Am. Chem. Jour., X. 57.

1888. Character and Effect of Illuminants present in Coal Gas. Technology Quarterly, II. 30.

1888. Natural Gas. Proc. Soc. Arts, M. I. T., 1887–88, p. 74.

1888. Bleaching. A Series of Articles in the Textile Record, beginning May, 1888.

1888. (With A. A. Noyes) Note on the Butines. Am. Chem. Jour., X. 430.

1889. The Composition of Boston Gas. Am. Gas Light Jour., L. 303.

1889. Cutch and its Uses in Textile Coloring. Textile Record, 1889, pp. 34, 66.

1890. (With Herbert C. Tuttle.) Lactic Acids and Lactates in Textile Coloring. Technology Quarterly, III. 287.

1890. Carbonization of Wool. Textile Record, XI. 64, 96.

1891. Notes upon the Estimation of Chlorine in Electrolyzed Solutions. Technology Quarterly, IV. 361.

Dr. Norton's influence on high scholarship at the Institute of Technology was felt in all departments of chemistry. The book of experiments in general chemistry, which he compiled in connection with the

late Professor Nichols, has been a most valued aid to instruction at the Institute, and has been largely used at other schools. In organic chemistry his instruction was on a high plane, yet he never lost sight of the importance, in a school of this character, of insisting on the industrial application of scientific research.

But it was in the teaching of industrial processes where he especially excelled. His lectures were listened to with eagerness by his pupils, who recognized the master who could deal with equal facility with the scientific basis of a process and with its economic merits. His range of subjects in industrial chemistry was very wide. Not only were the textile industries — bleaching, dyeing, printing, pigments, etc. — thoroughly taught, but the great industries of the world in their manifold variety received from him exhaustive treatment. His intimate acquaintance with the manufactures and manufacturers in New England kept him in close touch with the progress of all its industries.

Dr. Norton's career as a chemist and teacher is remarkable for the amount and variety of good work which he accomplished in his short span of life, which had not reached twoscore years at his death. The Institute of Technology, with which his life was so largely identified, lost in his death not only one of its most valued teachers, but one of the most useful members of its Faculty. His judgment, both in matters of the general policy of the Institute and of the minute details of organization, was always highly prized by his associates.

His personal character was singularly simple, direct, and truthful, and he was unselfishly devoted to his family, his friends, and his students.

In 1883 Dr. Norton married Alice Peloubet, who survives him, with five children.

1893. T. M. DROWN.

ANDREW PRESTON PEABODY.

DR. PEABODY was chosen into the Academy * at the close of a period when there had been quite a keen discussion as to the definition of the word "Sciences" in its title. The word Science and kindred words have certainly varied in their meaning more than once in the last two or three centuries. Forty or fifty years ago there was a division in the Academy as to whether it could be properly said

* He was elected a Resident Fellow in 1861, and was Vice-President from 1888 to 1892.

that there is a science of ethics or morals. His election may be counted as one evidence in many that the Academy of that day was ready to accept the wider definition.

For while he was an accurate mathematician who had pushed far his studies in the mathematics, and had proved himself a skilful and successful teacher, it was not as a mathematician that he was chosen into the Academy. The Academy could not have chosen any man in America whose election would more distinctly represent to our whole community its respect for the science of morals. In his work in literature, or in the pulpit, or as a Professor at Harvard, he would have wished to be recognized as one who believed that ethics is the first science which it behooves men to study. And he would have been glad, in whatever way, to have it understood that his business in life, first and last, was, by whatever effort, to make men better than he found them.

He was born in Beverly, Massachusetts, on the 19th of March, 1811. He entered Harvard College younger than any one else has entered it in this century, and graduated with high honor in the Class of 1826. He then became a tutor of mathematics, occupying a part of his time in studies which should prepare him for the Christian ministry. In 1833 he was ordained at Portsmouth, N. H., as colleague of Dr. Nathan Parker. He survived Dr. Parker, and remained at Portsmouth until 1860, when he returned to the University, to become Preacher to the University and Plummer Professor. He filled the active duties of this place until 1881, and was then named Emeritus Professor. He resided at Cambridge until his death, strong and well, and constantly called upon for public service in various capacities. When this took place, — the result, as it seemed, of an unfortunate fall, — he seemed as ready for duty as ever, and whoever dealt with him found it impossible to believe that he was so old a man.

In this long career he was never satisfied with performing what would be technically called the duties of his profession. One of his axioms, which he laid down in quite early life in an address to the divinity students at Cambridge, was this: "Every man should have a vocation and an avocation." His vocation was that of a faithful working minister of a very large congregation. He would choose one and another avocation from time to time, and fulfil all its obligations with vigor and the success which waits on vigor.

While he was yet at Portsmouth, he assumed, with a confidence which the event justified, the editorial charge of the North Ameri-

can Review, succeeding Dr. John Gorham Palfrey in that office. His direction of the Review was always fresh, and it was kept well up to the literary requisitions of the time. He enlisted a large number of writers who had not worked for it before, and the volumes published under his direction will be found to take a courageous and generous view of public exigency.

The years from 1830 to 1850 would generally be spoken of in New England history as the epoch in which the system of lyceum lectures was developing, and perhaps when it reached its culmination of usefulness. In the early days of such courses of lectures, public-spirited men undertook them, with a direct view, in which experience confirmed their foresight, of lifting up the level of popular education. Those were not the days of large "honorariums" for such service; they were days in which public speakers carried their best wares, and were thankful if a fit audience met them. Among the young men who devoted themselves heartily to the work of thus building up the lecture system, Dr. Peabody was foremost, and in after life he would frequently receive his reward when he found that some of his hearers of those days remembered counsels or information which he had then given. In later life, he delivered several of the courses of the Lowell Institute. Of these courses of lectures, one was printed in the year 1844, under the title, "Lectures on Christian Doctrine."

In his transfer to the University, he still had the vocation of a clergyman, and he had more than one avocation. He was the Preacher to the University, with the distinct understanding, under the very terms of the Plummer trust, that he was to be the counsellor and adviser of the undergraduates in any of their difficulties, spiritual, intellectual, and even physical. His devotion to this part of his task was such that the young men, particularly those from distant points, came to regard his house as a place where they might come for any counsel which they needed. He was himself proud of this confidence, and he never lost it, even after he retired from the nominal duties of his professorship. During this period he became an active member of the Academy, and his presence at our meetings will be gratefully remembered, as is his presence at the meeting of many other societies instituted for the best purposes of education or other philanthropy.

A valuable collection has been published of the baccalaureate sermons which, in more than twenty years, he addressed to as many classes as they graduated. Here is quite a well adjusted statement of the science of life. In no instance, among them all, did he satisfy himself with discussing, however brilliantly or carefully, what may

be called the matter-of-course or commonplace conditions of the occasion. These are not simply earnest addresses to young men who are his friends, to consider in general how great the change is from a college where they have studied to a world in which they must act. It will rather be found that he always puts himself in the place of some thoughtful, conscientious, eager young fellow in the Senior Class, who has faced some critical question among the infinite problems. He puts himself fairly in that man's place, asks that critical question aloud, and addresses himself to the answer. He does not attempt to conceal the difficulty by any blur of rhetoric. He owns that it is difficult. He states it carefully and clearly. And then he compels every man who hears him to help him out, as they work out the solution. What you are sure of is that, for after life, there is one position in the essentials of morals which in that day's farewell has been diligently considered. To have done that, if a man never did anything more, twenty times, for twenty classes, would be an achievement of which any man might be proud.

It is to be hoped that some Harvard man really interested in the history of America in the last half-century, will give us a monograph on the advance made in American life, as it can be shown — indeed, as it was largely led — by the pulpit of Harvard College between the days of Dr. Kirkland, in 1810, and the end of Dr. Peabody's active career. His own connection with Cambridge covers that period. He would have said, and the men of his time would say, that that was the moment when the College changed from a high school, and what we should call a poor high school at that, to a University. It will prove, when such a monograph is written, that the change can be traced all along in the words spoken from time to time in the College pulpit. To name Dr. Kirkland himself, both the Wares, Dr. Palfrey, Dr. Walker, among men who are dead, and Dr. Peabody in his longer line of service, is to name a line of leaders of men, all of whom were in touch with their times. In those sermons, so far as they can now be read, there will be found no cloister habit of counting jots and tittles. In the series of their instructions to three generations of men, may be found much of the inspiration under which these generations acted. Mr. Ralph Waldo Emerson said, in an address which I heard on a critical occasion, that he owed more to Harvard College from what he heard in the College Chapel than to any of her other instructions in his academic life.

Dr. Peabody was a fit successor in such work to James Walker, for so long a time an honored member of the Academy. It was not

in one sermon or in two that he taught his lessons. The undergraduates who heard him month after month knew that he had a plan of life. They knew what that plan was. They knew that it was not a plan for ten years or for seventy; it was the plan for the life of an immortal. It was not a plan for a lonely life, but for a life all wrought in with the life of the universe. It was the plan of a man who says "Our Father" when he prays, who knows what it is to be a son of God, who is engaged in his Father's affairs, who goes and comes on his Father's errands, creates as God creates, and enters into his Father's joys.

As has been intimated, Dr. Peabody was an omnivorous reader, and he was what the world now calls an all-round reader. I doubt if he ever read anything merely because other people read it, or from that vague and misleading notion that one must keep up with the times. He was never afraid of being behind the times. When he assumed the charge of the North American, he was very eager that it should not be guilty of mutual admiration, — an offence which it had been fairly accused of. When he gave up that journal, after five or six years' service, I said to him that he had given it up when he had "just begun to fight," when he was most fit for the business. "On the other hand," he said, "by the time a man has been an editor five years he should leave the helm. For by that time he has a circle of friends working with him, to whom he is under obligations. It becomes inevitable that he and his journal will want to be good to them, and their work will be spoken of as more important and permanent than it really is."

He was a counsellor and director in a hundred philanthropic trusts. Charity, education, peace, temperance, — whatever goes to happy homes and manly manhood, — for every movement or organization which involved these, he came to be regarded as of course an adviser and leader. Men of wealth were glad to take his counsel as to their use of it; and how glad he was when he could bring together here, face to face perhaps, the youngster who came eager for what Harvard could give, and the Mæcenas as glad that the boy should drink at her fountain.

Such activities brought him in touch with active men in all religious communions. "The doing the things which the Lord said," — the Christian spirit in which such men worked together, — made men prize him for what he was. People who are fond of method, and of stating in written language the results of the great movements of society, are always asking that the Christian Church shall devise some

symbol of its union which shall show that it is not divided at heart. The real symbol of its union is the willingness of its members to unite heartily in work for the upbuilding of the world, or for bringing in the kingdom of God. Quite indifferent to verbal statements with regard to unity, quite indifferent to forms of organization, Dr. Peabody, in the catholic and generous vigor by which he joined in every enterprise which seemed to him an enterprise of real philanthropy, was an evidence to all Christians of every communion that what is called the unity of Christianity is in no danger. No man in the circle of the Christian churches of New England, of whatever name or of whatever ritual, was so loved and honored by the men of all names and all rituals as was he.

1893. EDWARD EVERETT HALE.

GEORGE CHEYNE SHATTUCK.

GEORGE CHEYNE SHATTUCK was born in Boston, July 22, 1813. His parents were George C. and Eliza Cheever (Davis) Shattuck, both of New England parentage for many generations. The better part of his early education was at Round Hill, Northampton, under the influence of Joseph G. Cogswell, whom he always held in veneration. He was of the Class of 1831 in Harvard College, and afterwards studied in the Law School for one year, and in the Medical School for three years, taking his degree in 1835. His studies for his profession were continued in New England, London, and Paris, where he had the great advantage of Baron Louis as a teacher. Returning to Boston, he began practice with his father, then one of the eminent physicians of that city. He married Miss Anne H. Brune, sister of his classmate, Frederic W. Brune, of Baltimore, and from that time to his death resided in Boston, with occasional tours abroad. He became a visiting physician of the Massachusetts General Hospital in 1849, and served in that office for thirty-six years. He was a Professor in the Harvard Medical School from 1857 to 1874, and the Dean of the School for five years. He was President of the Massachusetts Medical Society from 1872 to 1874. These were his professional honors. Deeply attached to the Protestant Episcopal Church, he gave himself largely to its service in many diocesan boards and societies, and in the General Conventions and the Theological Seminary of that communion. His most conspicuous and lasting act in this relation was the

foundation of St. Paul's School in Concord, N. H. To this he gave an estate which had been his summer home for several years, making frequent gifts at later times to the amount of about one hundred thousand dollars. He was greatly revered as the founder of this school, and almost equally in his after years as a devoted layman of his Church thoughout the country. He died in Boston, after a protracted illness, March 22, 1893, leaving a widow, a married daughter, and two sons in his own profession.

This is a very bare outline of a highly serviceable and honorable career. A noble character was at the heart of it. He was simple, sincere, bountiful, thoughtful for others, and disinterested to an exceptional degree. His friends were very many, and the objects of his kindness and practical helpfulness were legion. His home was full of hospitality, and all about it lay the walks in which he served and loved his fellow men.

1893. SAMUEL ELIOT.

JOHN GREENLEAF WHITTIER.

JOHN GREENLEAF WHITTIER was born in Haverhill, Massachusetts, on December 17, 1807. His ancestors, in every line of the soundest Yankee stock, had resided from the earliest times in Essex County, or in the older regions of New Hampshire. The house in which he was born had been built by his emigrant ancestor, Thomas Whittier, who died at the age of seventy-six, in 1696, after above fifty years' residence in New England. In 1694, Joseph Whittier, son of the emigrant, and great-grandfather of the poet, had married the daughter of a well known Quaker. Probably from this time the immediate family of the poet had belonged to the Religious Society of Friends. In all other respects, their condition had been that of substantial New England farmers.

Amid the extreme diversity of religious views that marks our own time, and the efforts now so general among the New England clergy to emphasize the few things that religious people believe in common, and to neglect the many concerning which they radically differ, we are apt to think of religious divergences as verbal or formal. In general, I think, we are right. Modern Yankees, at all events, are not profound theologians. They are disposed either to take religion as they find it, or else, without

much ado, to select in place of their ancestral faith some creed or form of worship which they find socially or æsthetically more congenial. Sectarian differences nowadays certainly do not display themselves in obvious differences of character; and with people of ordinary parts, I take it, this has generally been the case at all times. With really serious natures the case is different. Those few people in any generation who seem instinctively aware of the tremendous seriousness of religion — the people whose presence in this world was perhaps the real basis of the Calvinistic doctrine of Election — are inevitably affected, often permanently, by the religious doctrine that surrounds their early years. Whatever else Whittier was, he was a profoundly religious man, who could not help taking life in earnest. To understand him at all, then, we must know something of the peculiar religious views which he never relinquished.

The Friends in New England, writes a gentleman who is now an earnest member of the Religious Society in question, "were Orthodox, in that they believed in God as Father, Son, and Holy Spirit; in Christ as truly one with the Father, yet also very man, and in the efficacy of His atonement for the forgiveness of sins. But the term 'Orthodox' in New England is usually taken to mean the tenets of the Westminster Confession. Whittier was trained to regard the extreme views of this Confession with aversion. He drank in the truth of the universal love of God to all men in Christian, Jewish, or Pagan lands; that God so *loved* the *world* that He sent His Son; that Christ died for *all* men, and His atonement availed for all who in every land accepted the light with which He enlightened their minds and consciences, and who, listening to His still small voice in the soul, turned in any true sense towards God, away from evil, and to the right and loving. Whittier thus drank in a spirit of universal love, a sense of oneness with all men, that fitted him to espouse and advocate the cause of the ignorant, the weak, the outcast,— the slave, the Indian, the heathen. It gave him sympathy with all loving saintly souls like Fénelon, Guion, and other Roman Catholics of like spirit, and nerved his manly indignant scorn of hard and cruel men that professed the name of 'Christian.' Whittier was trained to have a great reverence for the Bible. . . . He had read much in the journals of Friends. He had steeped his mind with their thoughts, and loved them because they were so saintly and yet so humbly unconscious of it.

"The title 'Quaker Poet' is a true one, not simply because he was a Friend by membership, but because he was permeated by the spirit of Quaker Christianity. It is true that Whittier was much broadened by association with men like Emerson, Longfellow, and others, Garrison especially; but he was to the end a Friend in his religion."

The letter from which I have quoted was addressed to a kinswoman of Whittier's and of my own, who has kindly sent me some notes of her recollection of Friends. Though some years younger than he, she was trained under similar influences. Her recollections, then, we may guess in some degree to have blended with his.

"During the early part of this century," she writes me, "I think the Society of Friends throughout the rural districts of New England retained in a great measure the stern, rigid simplicity and exclusiveness which characterized the religious people of the old Puritan days. They were thoroughly Orthodox,* and gave little heed to the Unitarian controversy among others. . . . Friends then had not, I think, *all* the aggressive fervor of the earlier days. There was a degree of lukewarmness; but they had among them many ministers,† untrained in the learning of the world, but full of spiritual life, who labored not only among Friends, but wherever they felt themselves called.

"The discipline of the Society was rigidly observed by most. Queries were answered quarterly, and looked after by appointed committee. I will give some of these queries, as they undoubtedly exerted some influence over the children, who often listened to them: —

"Are meetings for worship duly attended? hour ‡ observed? Are they preserved from sleeping or other unbecoming behavior?

"Are the Holy Scriptures frequently read?

"Do [Friends] avoid spirituous liquors except for medicine?

"Do they avoid unnecessary frequenting of taverns or other places of public resort?

"Are the poor looked after, and assisted in such business as they are capable of?

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* I. e. Trinitarian Christians, but not Calvinists. See the preceding letter.

† Among the Friends in general, men and women may alike be ministers; but a minister may not receive a salary.

‡ I. e. If no one feels called to speak, do they regularly wait for at least one hour in silence?

"Are [Friends] careful to inspect their affairs, punctual in promises?

"Do they live within the bounds of their income?

"Do they deal with offenders in the spirit of meekness? etc., etc.

"The children of Friends were early taught that there was a still small voice given them by their Heavenly Father, which would tell them when they were doing wrong.*

"In most cases they were taken regularly to meetings for worship,—often to those for discipline,—where they had to sit still on hard benches. They had no Sabbath schools, but in almost all families on First Day afternoon the children were required to listen to readings in the Holy Scriptures, and they were generally well informed in all Bible history. When Whittier was a little boy he once remarked he thought David could not have been a Friend, as he was a man of war.

"Music and dancing were not indulged in. Novels were forbidden. But they all the more enjoyed Milton, Young, Cowper, and histories when obtainable. It seems Whittier had none of these, at which I marvel, as his grandmother, who lived with them, was a Greenleaf, and they were literary people."

Without actually quoting these notes so kindly sent me, I could not have reproduced the effect they make on one who carefully reads them. To restate in one's own words the earnest faith they so tenderly express seems unsympathetic. But in more worldly phrase than theirs, what Whittier was taught and believed seems to have been this:—To all human beings God has given an inner light; to all He speaks with a still small voice. Follow the light, obey the voice, and all will be well. Evil-doers are they who neglect the light and the voice. Now the light and the voice are God's, so to all men who will attend they must ultimately show the same truth. If the voice call us to correct others, then, or the light shine upon manifest evil, it is God's will that we smite error, if so may be by revealing truth. If those who err be Friends, our duty bids us expostulate with them; and if they be obdurate, to present them for discipline, which may result in their exclusion from our Religious Society. And the still small voice really warns everybody that

* This doctrine of universal conscience seems the fundamental one of the Society of Friends.

certain lines of conduct are essentially bad, — among which are the drinking of spirits, the frequenting of taverns, indulgence in gaming, the use of oaths, and the enslavement of any human being.

In this firm faith, fortified from Scripture, that everybody really knows right from wrong, that many common lines of conduct are indubitably wrong, and that whoever follow such lines of conduct do so from wilful neglect of the inner light and the still small voice divinely vouchsafed them, Whittier was trained and lived. To this faith, involving the essential equality of all mankind, and the deliberate ungodliness of whoever by word or deed fails to recognize this equality, may be traced, I think, many of the peculiar characteristics that make him, even to those who mistrust the reforms in which he so passionately engaged himself, perhaps the least irritating of reformers. And not only was he trained from infancy in this faith, of which reform is the only logical expression in action; but his life from beginning to end was singularly remote from that heart-breaking experience of actual fact, in crowded and growing communities, which goes so far nowadays to disprove, for whoever will frankly recognize what is before him, the essential vitality of those parts of human nature which are best.

A barefoot boy to look at, an unswerving believer at heart in the inner light of the Friends, and by nature one of those calmly passionate Yankees who cannot help taking life in earnest, he grew up in days when the New England country was still pure in the possession of an unmixed race whose power of self-government has never been surpassed. His "Snow-Bound" relates his own memories of childhood; some of the sketches preserved in his prose works,* add pleasant touches to the better known pictures in his verses. He always had a hankering for literature. A strolling Scotch vagrant, hospitably treated to cheese and cider, sang him in payment some songs of Burns. At fourteen, he laid hands on a copy of Burns's Poems. These seem to have started him at writing. At seventeen he had written a poem on the "Exile's Departure" from the "shores of Hibernia," † which, in 1826, found its way into print in the New-

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* Notably, "Yankee Gypsies," and "Magicians and Witch Folk." Prose Works, Vol. I. pp. 326, 399.

† Poetical Works, Vol. IV. p. 333.

buryport "Free Press," then edited by William Lloyd Garrison. From 1827 to 1892 no year passed without verses which sooner or later came to publication. In 1826, before he was nineteen years old, he was visited while at work in the corn-field by Garrison, the young editor, who had been struck by the merit of his verses. The friendship thus begun proved lifelong. Had anything been needed to enhance the reformatory instincts of a Yankee Quaker, this first literary recognition, chancing to come from the man destined to be the most strenuous reformer of his time, would have been enough.

In his twentieth year, Whittier went to the Academy in Haverhill, where he spent two terms, and particularly distinguished himself in English composition. During a winter vacation he taught a country school. At twenty-one he was already a professional writer for some of the smaller newspapers. At twenty-three he was editor of the "Haverhill Gazette"; and before he was twenty-four he was made editor of the "New England Weekly Review," a paper published at Hartford, Conn. At the end of a year and a half, he resigned this office, on the ground of ill-health, and returned to Massachusetts. Meanwhile he had published a small volume of "New England Legends."

At this time, Garrison had just established "The Liberator" in Boston. The movement for the abolition of slavery was fairly begun. Into this movement Whittier threw himself with all his might. For thirty years he constantly advocated it in both prose and verse. He was a member of the Antislavery Convention at Philadelphia, in 1833.* He was attacked by a mob at Haverhill, in 1834; and by a worse one at Concord, New Hampshire, in 1835. In this year he was for one term a member of the General Court. In 1837 he went to New York, as a secretary of the National Antislavery Society. Early in 1838 he was made editor of the "Pennyslvania Freeman," a journal devoted to the cause of abolition, published at Philadelphia. In May, 1838, the office of this paper, together with Pennsylvania Hall, just erected for the purpose of providing the Abolitionists with a regular place of meeting, was burned by a mob. In 1840 he resigned his charge of the "Freeman," and rejoined his mother and sister, who had moved to Amesbury, Massachusetts. Here, henceforth, was his legal residence.

* See his vivid reminiscences of it, Prose Works, Vol. III. p. 171.

From this time on, his life was remarkably uneventful. Shy in temperament, and generally troubled by that sort of robust poor health which frequently accompanies total abstinence, he lived secluded in the Yankee country for the better part of fifty-two years. He wrote a great deal, but rarely, it is said, above half an hour at a time. In 1849 a collection of his poems was published; in 1857 came another, this time from his final publishers, Ticknor and Fields. He had now become a recognized literary figure. He was concerned in the starting of "The Atlantic Monthly." The temper of the North was beginning to come over to the side of abolition. In the war, dreadful as such an event was to his religious convictions, he saw the hand of God destroying the great evil of slavery. He had always adhered to that branch of the Antislavery party which believed in opposing the national evil by regular political means. He was an ardent member of the Republican party; and the close of the war, which found his principles victorious, found him in public estimation a great man.

In 1871 he was made a Fellow of the American Academy. It is not remembered that he ever attended a meeting. General society, even in its severer forms, he never found congenial. An occasional visit to intimate friends in Boston, and of a summer to the Isle of Shoals, or later to the hill country about Chocorua, were the chief incidents in his life. But he never stopped writing. His "Birthday Greeting," sent to Dr. Holmes on the 29th of August, 1892, was written only a few weeks before his death. He died, in his eighty-fifth year, at Hampton Falls, New Hampshire, on September 7, 1892.

During his last years he made a final collection of his writings, with a few brief notes.* It is in seven volumes, four of verse and three of prose. The arrangement is a little confusing. He classified his works under a number of not very definite heads, and under each head printed his material chronologically. The first volume contains "Narrative and Legendary Poems," from 1830 to 1888; the second, "Poems of Nature," from 1830 to 1886, "Poems Subjective and Reminiscent," from 1841 to 1887, and "Religious Poems," from 1830 to 1886; the third, "Antislavery Poems," beginning with one to William Lloyd Garrison in 1832, and ending with one to his memory in 1879, and "Songs

* "The Writings of John Greenleaf Whittier," Riverside Press, 1893.

of Labor and Reform" from 1838 to 1887; the fourth contains "Personal Poems" from 1834 to 1886, "Occasional Poems" from 1852 to 1888, and reprints of "The Tent on the Beach," originally published in 1867, and of his last volume, "At Sundown," which originally appeared shortly after his death. In an Appendix are youthful poems as early as 1825. The prose works are classified in a similarly confusing way. There is a volume of "Tales and Sketches," including his essay in historical fiction, "Margaret Smith's Journal in the Province of Massachusetts Bay, 1678–79"; a volume of "Old Portraits and Modern Sketches," "Personal Sketches and Tributes," and "Historical Papers"; and a volume of papers concerning "The Conflict with Slavery," "Reform and Politics," "The Inner Life," and "Criticism."

This bewildering arrangement of the work of sixty-seven years is characteristic. By far the longest article in any of the seven volumes is "Margaret Smith's Journal," which covers one hundred and eighty-six pages. By far the greater part of all the work consists of verses or papers which could easily have been written at a short sitting. Uncertain health, the early practice of journalism, and the lack of that higher education which demands prolonged intellectual effort in a single direction, seem to have combined to deprive him of the power of sustained literary labor. As he writes of himself,

> "His good was mainly an intent,
> His evil not of forethought done;
> The work he wrought was rarely meant,
> Or finished as begun.
>
> . . . .
>
> "The words he spake, the thoughts he penned,
> Are mortal as his hand and brain,
> But, if they served the Master's end,
> He has not lived in vain!" *

That last stanza is unduly modest. There are passages in Whittier's works which have strength and merit of a kind that ought to survive. But of his works as wholes it is true. There is hardly one in which the vital passages are not half buried in irrelevance, redundance, or commonplace. And, as I have said, the very confusion in which he finally presented his writings to

* "My Namesake," Poetical Works, Vol. II. pp. 118, 121.

posterity is typical of his inability to handle anything on a large scale.

To one who amid this confusion sets himself to discover the characteristic traits of the work, the first salient features are not its merits. Whittier was certainly precocious. Certainly, too, the power he displayed in youth did not meet the common fate of precocity. But the change from his earliest work to his latest is surprisingly slight. At seventeen he wrote of the Merrimac:

"Oh, lovely the scene, when the gray misty vapor
  Of morning is lifted from Merrimac's shore;
When the firefly, lighting his wild gleaming taper,
  The dimly seen lowlands comes glimmering o'er;
When on thy calm surface the moonbeam falls brightly,
  And the dull bird of night is his covert forsaking,
When the whippoorwill's notes from thy margin sound lightly,
  And break on the sound which thy small waves are making." *

At thirty-three he wrote of it again:

"But look! the yellow light no more
Streams down on wave and verdant shore;
And clearly on the calm air swells
The twilight voice of distant bells.
From Ocean's bosom, white and thin,
The mists come slowly rolling in;
Hills, woods, the river's rocky rim,
Amidst the sea-like vapor swim,
While yonder lonely coast-light, set
Within its wave-washed minaret,
Half quenched, a beamless star and pale,
Shines dimly through its cloudy veil!" †

At fifty-nine he wrote of the light-house visible from Hampton Beach:

"Just then the ocean seemed
  To lift a half-faced moon in sight;
And shoreward o'er the waters gleamed,
  From crest to crest, a line of light.

. . . . .

Silently for a space each eye
  Upon that sudden glory turned:
Cool from the land the breeze blew by,
  The tent-ropes flapped, the long beach churned

* Poetical Works, Vol. IV. p. 336. † Poetical Works, Vol. II. p. 12.

Its waves to foam; on either hand
Stretched, far as sight, the hills of sand;
With bays of marsh, and capes of bush and tree,
The wood's black shore-line loomed beyond the meadowy sea." *

And as he dealt with Nature here, for above forty years simply looking and telling just what he saw, so he dealt with everything from beginning to end. For sixty-seven years his work retains its chief characteristics, with remarkably slight alteration.

The most salient of these characteristics, as I have said, are not the merits. The lines I have cited have an obvious air of commonplace. It is deceptive. As one grows to know them, and the hundreds of others for which I must let them stand, one begins insensibly to realize that the power of selective observation which underlies them is of no common order. But commonplace they merely look, and commonplace beyond all doubt are endless passages throughout Whittier's verse. The man lacked the saving grace of humor. In all the seven volumes I have found but one passage that really amused me. This is an account in "Yankee Gypsies" † of how a drunken vagabond broke into the Whittier homestead while the men were away, and made formal love to the dismayed grandmother who was born Greenleaf. In Whittier's verse, this lack of humor is sometimes startling. In a poem ‡ where a Yankee stage-driver describes the profoundly gracious merits of a passenger, who once made him stop while she sketched a panoramic view, occurs this stanza:

"'As good as fair; it seemed her joy
To comfort and to give;
My poor, sick wife and cripple boy
Will bless her while they live!'
The tremor in the driver's tone
His manhood did not shame:
'I dare say, sir, you may have known —'
He named a well-known name."

And in a poem § commemorating a railway conductor who lost his life in an accident come these passages:

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* Poetical Works, Vol. IV. p. 281.
† Prose Works, Vol. I. p. 339.
‡ "The Hill-Top," Poetical Works, Vol. IV. p. 58.
§ "Conductor Bradley," Poetical Works, Vol. I. p. 359.

"Lo! the ghastly lips of pain,
Dead to all thought save duty's, moved again:
'Put out the signals for the other train!'

"No nobler utterance since the world began
From lips of saint or martyr ever ran,
Electric, through the sympathies of man.

. . . . .

"Others he saved, himself he could not save.

"Nay, the lost life *was* saved. He is not dead
Who in his record still the earth shall tread
With God's clear aureole shining round his head."

The noble simplicity of the second passage does something to atone for the appalling literalness and the monstrous hyperbole of the first. But one wonders if any other writer of real merit could ever have deliberately reprinted such passages side by side.

His lack of humor, then, was serious. So, to a less degree, was his lack of artistic feeling. The remarkably narrow range of his metrical forms, the astonishing errors of his rhymes, are salient and familiar features of his verse. And another defect must have been apparent to whoever has read even the passages that I have already quoted. He had little strength of creative imagination. His poetical figures are almost always both obvious and trite. A lighthouse resembles a minaret; the woods bordering a salt meadow are like the shore bordering the actual sea; a good man, when dead, is provided with an aureole; and so on. The moralizing passages frequent throughout his work display the same weakness. If in his lack of humor he sinks below the commonplace, there is nothing in the technical form of his work, or in the creative power of his imagination, that often rises above it.

Yet as one grows to know the work of Whittier, one grows insensibly to feel that essentially it is far from commonplace, that it really deserves the importance accorded to it in contemporary literature, that no small part of it will probably outlive the age to which it was addressed, and perhaps even the work of any other contemporary American. I have purposely touched on his faults, and put them all together. Not to have recognized them would have been deliberately not to see him as he was. In growing to know his work, these, I think, are what one first

remarks. By and by one finds them forgotten in a sense that this poet whom one has grown to know has in him lasting elements for which greatness is perhaps no undue name. Throughout his sixty-seven years of work one feels with growing admiration a constant simplicity of feeling and of phrase, as pure as the country air he loved to breathe. One feels, too, constant, unswerving purity of nature, of motive, of life. And if one feel, besides, the limits of thought and of experience that made such purity and simplicity possible throughout eighty-five years of human existence, one is none the sadder for that. What Whittier voiced was a life that could be lived in our own New England through the stormiest years of our Nineteenth Century. Limited though it were, that life throughout, in thought, in feeling, in word, in act, was simple and pure,—commonplace, if you will, in more aspects than one; but in one never commonplace,—never for a moment was it ignoble. It has been the fortune of New England, above other parts of our country, to fix the standards and the ideals that have hitherto prevailed throughout the continent of North America. There is courage in the thought that even to our own time New England could bring forth and sustain such noble purity as his.

To feel how genuine, how pure, how noble, the man was, with all his limits, we must consider his work in some detail. His own classification of it, as I have said, is confusing. His prose work, once for all, is of little importance. It shows him possessed of a quietly pleasant narrative style, and of a controversial style, of considerable force. But it phrases, I think, little or nothing that is not equally phrased in his more favorite vehicle of verse. I shall discuss, then, chiefly his verse: first that part of it which most reveals himself; then that which deals with his own experience of Nature; then his romantic narratives; and finally the work which he himself deemed chief,—his lifelong advocacy of human freedom.

If masterpiece be not an extravagant term for any work of Whittier's, we may perhaps call "Snow-Bound" his masterpiece.* At fifty-nine, when almost all of his immediate family were dead, he wrote in tenderly simple verse this account of his earliest memories. "Flemish pictures of old days," he calls it toward the end. The phrase would be apt, but that it ignores

* Poetical Works, Vol. II. pp. 134–159.

what seems to me the most notable trait of all. Flemish pictures one thinks of as pictures of a peasantry. In "Snow-Bound" we have a country folk very rare in human history. No life could be much simpler, much more remote from luxurious comfort or lazy ease, than the life that is pictured here. But for all their brave rusticity, these sturdy Yankees, toiling in summer on their rocky farms, resting perforce in such winter as buried them in almost Arctic snow-drifts, are no peasants. What makes them what they are is that they are still lords of themselves and of the soil they till. Simple with all the simplicity of hereditary farming folk, they are at the same time gentle with the unconscious grace of people who know no earthly superiors. This is the phase of human nature that Whittier knew first and best. This is what he assumed and believed that all mankind might be. And this is the stuff of which any sound democracy must be made. So of this stormy evening he writes:

"Shut in from all the world without,
We sat the clean-winged hearth about,
Content to let the north-wind roar
In baffled rage at pane and door,
While the red logs before us beat
The frost-line back with tropic heat;
And ever, when a louder blast
Shook beam and rafter as it passed,
The merrier up its roaring draught
The great throat of the chimney laughed;
The house-dog on his paws outspread
Laid to the fire his drowsy head,
The cat's dark silhouette on the wall
A couchant tiger's seemed to fall;
And, for the winter's fireside meet,
Between the andirons' straddling feet,
The mug of cider * simmered slow,
The apples sputtered in a row,
And, close at hand, the basket stood
With nuts from brown October's wood."

This vivid simplicity of description is generally recognized. Less obvious, I think, and less certainly known, is the occasional ultimate simplicity of phrase which makes certain lines of

* It has generally been customary in New England, I think, not to deem cider spirituous.

"Snow-Bound" notable. Take this reference to those that are no more:

> "We turn the pages that they read,
> Their written words we linger o'er,
> But *in the sun they cast no shade,*
> No voice is heard, no sign is made,
> No step is on the conscious floor!"

Or again, take this couplet about the maiden aunt, so familiar a figure in New England households:

> "All unprofaned she held apart
> The virgin fancies of the heart."

Or again, these lines for once imaginative:

> "How many a poor one's blessing went
> With thee beneath *the low green tent*
> *Whose curtain never outward swings!*"

Or again:

> "But still I wait with ear and eye
> For something gone which should be nigh,
> *A loss in all familiar things,*
> In flower that blooms, and bird that sings."

Or again still:

> "And while in life's late afternoon,
> When cool and long the shadows grow,
> I walk to meet *the night that soon*
> *Shall shape and shadow overflow,*
> I cannot feel that thou art far."

It was from such memories as these, thus remembered, that he went to his work in the world. And the very first poem in his class of "Subjective and Reminiscent" suggests, what rarely appears in his writing, that he had tender memories of a less domestic nature. For these verses, addressed at the age of twenty-three to a lady of Calvinistic tendencies, from whom he seems to have been long parted, contain this passage:

> "Ere this, thy quiet eye hath smiled
> My picture of thy youth to see,
> When, half a woman, half a child,
> Thy very artlessness beguiled,
> And *folly's self seemed wise in thee.*" *

* "Memories," Poetical Works, Vol. II. p. 96.

His chief work, as we have seen, he believed to be the work of reform. The personal effects of such work he felt sensibly. At thirty-five, he wrote of himself for a lady's album:

> "A banished name from Fashion's sphere,
> A lay unheard of Beauty's ear,
> Forbid, disowned, — what do they here?" *

At forty-five, in lines to his Namesake,† he draws his own portrait:

> "Some blamed him, some believed him good,
> The truth lay doubtless 'twixt the two;
> He reconciled as best he could
> Old faith and fancies new.
>
> . . . . . .
>
> "He loved his friends, forgave his foes;
> And, if his words were harsh at times,
> He spared his fellow men, — his blows
> Fell only on their crimes.
>
> "He loved the good and wise, but found
> His human heart to all akin
> Who met him on the common ground
> Of suffering and of sin.
>
> . . . . . .
>
> "Ill served his tides of feeling strong
> To turn the common mills of use;
> And, over restless wings of song,
> His birthright garb hung loose!
>
> "His eye was beauty's powerless slave,
> And his the ear which discord pains;
> Few guessed beneath his aspect grave
> What passions strove in chains.
>
> . . . . . .
>
> "He worshipped as his fathers did,
> And kept the faith of childish days,
> And, howsoe'er he strayed or slid,
> He loved the good old ways, —
>
> "The simple tastes, the kindly traits,
> The tranquil air, and gentle speech,
> The silence of the soul that waits
> For more than man to teach.
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> . . . . . .

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* "Ego," Poetical Works, Vol. II. p. 102. † Ibid., Vol. II. p. 116.

"And listening, with his forehead bowed,
Heard the Divine compassion fill
The pauses of the trump and cloud
With whispers small and still."

However, his actual belief may have been affected by the immense growth of devout free thought about him, he never for a moment faltered in faith that the inner light of the Friends is real. On his sixty-fourth birthday he wrote:

"God is, and all is well!

"His light shines on me from above,
His low voice speaks within, —
The patience of immortal love
Outwearying mortal sin." *

And again, at seventy-eight:

"By all that He requires of me,
I know what God himself must be.

"No picture to my aid I call,
I shape no image in my prayer;
I only know in Him is all
Of life, light, beauty, everywhere." †

In his last volume are some lines, that must have been written about this time, concerning an outdoor reception, where some young girls had pleased him:

"But though I feel, with Solomon,
'T is pleasant to behold the sun,
I would not if I could repeat
A life which still is good and sweet;
I keep in age, as in my prime,
A not uncheerful step with time, . . .
On easy terms with law and fate,
For what must be I calmly wait,
And trust the path I cannot see, —
That God is good sufficeth me." ‡

With less quotation I could hardly have given the effect of Whittier's personality that emerges from these self-expressive

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* "My Birthday," Poetical Works, Vol. II. p. 164.
† "Revelation," Poetical Works, Vol. II. p. 343.
‡ "An Outdoor Reception," Poetical Works, Vol. IV. p. 297.

poems. Superficially commonplace in their simplicity, they really express a character in which the simple virtues of New England are so firmly rooted that by very force of its unassuming strength it becomes strongly individual. It is pervaded, however, with true Yankee melancholy, for which, so far as we have yet seen, there was no help but what might be found in fervent religion and its accompanying duties. But Whittier had throughout life another resource. To quote once more from the poem to his Namesake, from which I have already quoted much:

> "Yet Heaven was kind, and here a bird
> And there a flower beguiled his way;
> And, cool, in summer noons, he heard
> The fountains plash and play.
>
> "On all his sad or restless moods
> The patient peace of Nature stole;
> The quiet of the fields and woods
> Sank deep into his soul."

In other words, Whittier found in the contemplation of New England landscape the most constant, lasting pleasure of his long life.

In his collected works, the poems he classifies as "of Nature" fill only eighty-six pages. In reality, poetry of Nature pervades his whole work. Under this head, for example, may clearly fall the first lines to the Merrimac which I quoted, and the passage concerning nightfall on Hampton Beach, as well as a great part of "Snow-Bound." Yet all these are classified elsewhere. So are numberless passages like the following, which is apparently to his mind either narrative or legendary:

> "Along the roadside, like the flowers of gold
> The tawny Incas for their gardens wrought,
> Heavy with sunshine droops the golden-rod,
> And the red pennons of the cardinal-flowers
> Hang motionless upon their upright staves.
> The sky is hot and hazy, and the wind,
> Wing-weary with its long flight from the south,
> Unfelt; yet, closely scanned, yon maple leaf
> With faintest motion, as one stirs in dreams,
> Confesses it. The locust by the wall
> Stabs the noon-silence with his sharp alarm.
> A single hay-cart down the dusty road

Creaks slowly, with its driver fast asleep
On the load's top. Against the neighboring hill,
Huddled along the stone wall's shady side,
The sheep show white, as if a snowdrift still
Defied the dog-star. Through the open door
A drowsy smell of flowers — gray heliotrope,
And white sweet clover, and shy mignonette —
Comes faintly in, and silent chorus lends
To the pervading symphony of peace." *

Everywhere in Whittier's work one may find such pictures. Quite to appreciate them, perhaps, one must know the country they deal with. The regions of New England that Whittier knew have a character peculiarly their own. The rocky coast between Cape Ann and the Piscataqua, broken by long stretches of beach; the marshes, dotted with great stacks of salt hay, stretching back to the woods or the farms of the solid land; the rolling country, with its elms and pines, its gnarled apple orchards, its gray wooden farmhouses; and almost within sight the lower spurs of the New Hampshire hills, bristling with a stubble of young woods, are unlike any other country I have known. Such subtle impressions as mark the individuality of a region are unmistakable, but almost beyond the power of words to phrase. Perhaps the trait which most distinguishes this country that Whittier so knew and loved is a nearer approach to the suggestion of a romantic past than is common in North America. Far as the eye can reach or the foot travel, this region has been the home of our own race for above two centuries. It has its own traditions, its own legends. It is humanized in a way almost European. Yet its legends belong to a past not of civilized or mediæval grandeur, but of savage wildness. And its actual prosperity is past or passing, — but for great factories, swarming with foreign operatives, or for summer visitors, who come to idle in regions where the toil of the past generations bred the race that has tamed a savage continent.

In these regions, it was Whittier's lot to know the last days of the olden time and the first of the new. He loved the old days for their hardy virtues; his faith in human nature, always guided by the inner light, allowed him no misgivings for the future. In "Cobbler Keezar's Vision," † the German wizard finds

* "Among the Hills," Poetical Works, Vol. I. p. 260. To be sure, this extract is from the Prelude.

† Poetical Works, Vol. I. p. 241.

the Merrimac of the future, with its scores of mill-wheels and its white-walled farmhouses and its floating flags of freedom, a lovelier sight than his memories of the vine-clad Rhine, with its clowns and puppets, its flagons and its despotism. Whittier found the Merrimac lovelier himself, — a task in which he was probably helped by the narrow limits of his travels. He loved the Nature about him. He found in it something that constantly rewarded and strengthened his life-long love.

Expressing this constant delight in the country that his verses have made peculiarly his own, he accomplished, half unwittingly, the work which I believe will ultimately be thought his best. One may question, if one choose, the merit of his personal and religious poems; one may find his romantic narratives trivial, and his passionate advocacy of reform blind, dangerous, truculent; but one cannot deny that he has seen the landscapes of his own New England with an eye as searching as it was loving, or that he has told us what he saw so simply, so truly, so constantly, that, however time and chance may change in years to come the face of the regions he knew so well, the things he saw and loved may be seen and loved throughout time by all posterity. The peculiar character of his poetry of Nature is that it is not interpretative, but faithfully representative. The examples of it already quoted are enough to show this trait. There are critics, then, and real lovers of poetry, who find his work harshly literal, unimaginative, prosaic. Such critics, I think, will not let themselves sympathize with the exquisitely sympathetic sense of fact that underlies his utter simplicity. When he tried to interpret, he added nothing to his work. When he was content to tell us what he saw, he showed us constantly what many of us should never have seen for ourselves; and this he showed so truly that, as proves in the centuries true of the art which the centuries pronounce great, each one of us may in turn interpret it anew for himself, just as each may interpret for himself the life that passes before his living eyes.

In the constant strength of his instinctive fidelity to Nature, I think Whittier distinguishes himself from almost all other American men of letters. In most of our literature there is a quality of consciousness. Sometimes this takes the form of aggressive cleverness; sometimes it deliberately assumes the traditional dignity of culture; often — and perhaps most characteristically — it half consciously, half unwittingly, follows or re-

vives tradition. As somebody has extravagantly said, American verse swarms with nightingales, — a bird unknown on this continent. For this state of things there is a reason that these perhaps imaginary nightingales typify. An American would not be a true son of the fathers if he did not instinctively love tradition. The emigrants brought from the Old World fireside tales of things and folks, of pomps and grandeurs, of comedies and tragedies, that their children could never know in the flesh. And history has moved fast with us, and society has been overturned more than once. And Western children to-day are listening to such stories of New England as Yankee children of the early days heard about Old England itself. This love of tradition, which shows itself perhaps most markedly in the passion for genealogy that permeates New England, is a prime trait of the true Yankee. And Whittier was as true a Yankee as ever lived. His first published volume, we remember, was a volume of "New England Legends." New England legends he continued to write almost all his life; and as his reading extended, he wrote many other legends, too, of regions and races that he had never known in the flesh.

Of the latter little need be said. They are not, I think, profoundly characteristic. He got them from books, and he put them in other books, where their simple ballad form makes them pleasantly readable. He generally managed to infuse into them a certain amount of blameless moralizing, which does not enhance their stimulating quality. On the whole, one may class them with that great body of innocuous American verse which is permeated with the innocent unreality of conscious culture.

The New England legends are of firmer stuff. In his prose works one finds some of the material that goes to make them. "Charms and Fairy Faith," and "Magicians and Witch Folk," * tell of such actual traditions as were kept alive at the snow-bound fireside. "Margaret Smith's Journal," while no permanent contribution to historical fiction, is so true a picture of the Seventeenth Century in New England as to prove beyond peradventure the solidity of Whittier's study in local history. And verses like these show how well he knew the ancestral Puritans:

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* Prose Works, Vol. I. pp. 385, 399.

"With the memory of that morning by the summer sea I blend
A wild and wondrous story, by the younger Mather penned,
In that quaint *Magnalia Christi*, with all strange and marvellous things,
Heaped up huge and undigested, like the chaos Ovid sings.

"Dear to me these far, faint glimpses of the dual life of old,
Inward, grand with awe and reverence; outward, mean and coarse and cold;
Gleams of mystic beauty playing over dull and vulgar clay,
Golden-threaded fancies weaving in a web of hodden gray." *

His romantic and legendary narratives of New England, then, have much of the true flavor of the soil. He seems to have been haunted, however, by a lurking Yankee conscience, that constantly suggested doubts as to whether it is quite right to tell a good story just for its own sake. His introduction to the "Tent on the Beach," † the volume which contained on the whole his most effective narrative poems, is distinctly apologetic. Here, at sixty-six, he writes:

"I would not sin, in this half playful strain, —
Too light, perhaps, for serious years, though born
Of the enforced leisure of slow pain, —
Against the pure ideal which has drawn
My feet to follow its far-shining gleam.

And his narratives of New England tradition generally deal with such phases of it as have perceptible didactic significance. Naturally, he represents the Quakers heroically. A typical stanza is this, from the "King's Missive," ‡ written at seventy-two:

"'Off with the knave's hat!' An angry hand
Smote down the offence; but the wearer said,
With a quiet smile, 'By the King's command
I bear his message and stand in his stead.'
In the Governor's hand a missive he laid
With the royal arms on its seal displayed;
And the proud man spake as he glanced thereat,
Uncovering, 'Give Mr. Shattuck his hat.'"

* "The Garrison of Cape Ann," Poetical Works, Vol. I. p. 166.

† Poetical Works, Vol. IV. p. 227.

‡ Ibid., Vol. I. p. 383. We must remember that Quaker principles forbade salutation by uncovering the head.

Indubitably didactic in motive, too, are those two narrative poems of his which are apparently most familiar, — "Maud Muller," * written at forty-six, and "Skipper Ireson's Ride," † written at forty-nine. The merits and the limits of his work in this kind are patent in Maud Muller. The little poem is very simple, and in its conventional sentimentality is very acceptable to the great American public. In its presentation of a Yankee judge in the character of a knightly hero of romance, it is artlessly consonant with the social ideals of the Yankee country; so, too, in its tacit assumption that the good looks of a barefoot country beauty would really have been more congenial life companions in an eminent legal career than the rich dower and the fashionable tendencies of the lady the Judge ultimately married, — in deference to

> "his sisters proud and cold,
> And his mother, vain of her rank and gold."

If this sort of thing were canting, it would be abominable. What saves it is that it rings true. The man meant it seriously. We may smile at his simplicity, if we like; but we can hardly help loving him for it. Indeed, it is almost enough to make us forgive that invidiously dreadful rhyme:

> "For of all sad words of tongue or pen,
> The saddest are these: 'It might have been!'"

"Skipper Ireson's Ride," on the other hand, has much of the true ballad quality:

> "Body of turkey, head of owl,
> Wings a-droop like a rained-on fowl,
> Feathered and ruffled in every part,
> Skipper Ireson stood in the cart.
> Scores of women, old and young,
> Strong of muscle, and glib of tongue,
> Pushed and pulled up the rocky lane,
> Shouting and singing the shrill refrain:
> 'Here 's Flud Oirson, fur his horrd horrt,
> Torr'd an' futherr'd an' corr'd in a corrt
> By the women o' Morble'ead!'"

Such a subject as that stirred the Yankee Quaker to the depths. A human being, deaf to the still small voice, had acted devil-

* Poetical Works, Vol. I. p. 148. † Ibid., p. 174.

ishly. The weakest creatures of his seaside home had risen up against him in a body; and, not overstepping the bounds of due punishment, had held him up lastingly to public scorn and detestation. It is perhaps instructive, in connection with such reforming enthusiasm as pervades this spirited ballad, to learn from a note in the final edition, that twenty-two years after the original publication Whittier was creditably informed that Ireson had really been innocent.* Against the skipper's will, it appeared, his refractory crew had compelled him to desert his sinking townsfolk; and then, to screen themselves, they had falsely accused him, with the direful result commemorated by the poet. His answer to his informant is characteristic: "I have now no doubt that thy version of Skipper Ireson's ride is the correct one. My verse was founded solely on a fragment of rhyme which I heard from one of my early schoolmates, a native of Marblehead. I supposed the story to which it referred dated back at least a century. I knew nothing of the participators, and the narrative of the ballad was pure fancy. I am glad for the sake of truth and justice that the real facts are given in thy book. I certainly would not knowingly do injustice to any one, dead or living." And having thus introductively done full justice to the memory of poor Floyd Ireson, he proceeds to reprint his ballad.

In touching these narrative and legendary poems of Whittier, I have perhaps allowed myself to lay undue emphasis on phases of them that are not their best. One and all, I think, we may call simple, earnest, artless, and beautifully true to the native traditions and temper of New England. In that very fact, however, which is what I have tried to emphasize, lies their weakness as literature. The temper of New England is essentially serious, always uncomfortable if it cannot defend itself on firm ethical ground. And thoroughly good narrative ought to be as free from obvious ethical admixture as are the exquisitely pure descriptions of New England landscape which, as I have said, seem to me Whittier's most lasting work. At times, these narratives of his blend almost inextricably with his poems of Nature; from the narratives may be selected extracts which in simple descriptive power are as beautiful as anything Whittier ever did. But, in general, the impression that these narratives

* Poetical Works, Vol. I. p. 174.

make is one of saturation with the traditional ethical ideas of New England, curiously combined with that constant reliance on inner inspiration toward the Right which is the fundamental tenet of the Quaker faith. All men are really equal, all ought to be really free; let them be free, and all they have to do is to follow the inner light. And here these narrative poems touch close, on the other hand, the works which Whittier deemed his best, — his works for reform. A passage like this, which closes "The King's Missive," * might have belonged to either class:

> "The Puritan spirit, perishing not,
>   To Concord's yeomen the signal sent,
> And spoke in the voice of the cannon-shot
>   That severed the chains of a continent.
> With its gentle message of peace and good-will
> The thought of the Quaker is living still,
> And the freedom of soul he prophesied
> Is gospel and law where the martyrs died."

From beginning to end, Whittier was an honest champion of human freedom. We have seen enough of the peculiar religious faith from which he never swerved to understand how inevitable such a position must have seemed to him. We have seen enough of his own almost childlike simplicity and honesty of temperament to understand the whole-souled, unhesitating vigor with which he threw himself into the task to which he felt himself called. To every human being God has given the inner light. Leave human beings free to act, then, as God meant them to act, and God's will shall be done. The voice of the people is literally the voice of God; it is the concrete, numerical expression of the whisperings of the still small voice. Whether the human form to which the voice whispers be European, Asiatic, African, or American makes no manner of difference. Difference of race is merely a variety of complexion. A majority of negroes is as divinely true a force as a majority of Puritan farmers. For are not all alike made in God's image, all alike human, all alike accessible to the inner light and the still small voice which can lead only towards the truth? Admit such premises, — and Whittier never doubted them for a moment, — and there is room for only one conclusion: whatever opposes any form of human freedom is against God's will. Not to pro-

* Poetical Works, Vol. I. p. 386. Written at seventy-two.

claim this truth, not to assert it in every word and deed, is to be what Whittier could never have been, — a deliberate coward.

In the course of his life he advocated. more reforms than one. His conduct in regard to the abolition of slavery, however, is typical of his conduct in all. It will serve our purpose to consider that alone.

Quite to appreciate the courage implied in the public assertion of antislavery opinions sixty years ago demands to-day no small effort of imagination. It was greater than that which would be shown to-day by an ambitious aspirant for public honors, who should honestly and openly question the wisdom of the ultimate abolition of slavery. To-day, such an opinion, which was the dominant opinion in 1830, could result in no worse harm than political ridicule or neglect. It would hardly diminish the number or the cordiality of one's social invitations. In 1830 an Abolitionist was held little less than treasonable. Social ostracism was almost certainly his due. His very person was not safe from public attack; and the blind hostility of the mob — which for some years to come was far too noisy to detect the whisperings of any still small voice — was confirmed by that profoundly honest belief in the public duty of maintaining existing institutions which has always characterized the better classes in any community of British origin. Perhaps the closest analogy which we can imagine to-day to the Abolitionists of 1833 would be a body of earnest, God-fearing men who should be convinced that God bade them cry out against the institution of marriage.

In the face of such a state of public opinion as this, Whittier never for a moment faltered. He knew what was right. The one curse spared him was the curse of even momentary doubt. Shy in temperament, loving most of all the simple seclusion of his native county, he never hesitated to speak and to act with all his power for the cause of human freedom. That enfranchisement, in the broadest sense, could possibly result only in a new phase of evil, he never dreamt to the end. He was a man. Negroes, Indians, Chinamen, Polish Jews, are men too. Let all have equal rights, all an equal voice, all be equal in the sight of man as they are eternally equal in the sight of God. What he actually did, we have seen in our brief record of his life. That brief record has been enough to show that the dreadful fact of slavery was a fact of which he had little direct knowledge. He

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was at Washington in 1845. Apart from that, his knowledge of actual slaves must have been derived chiefly from fugitives, whose versions of their experience must wholly have confirmed his most extreme views. But what mattered that? When one knows a thing evil, one need not study it in detail to know that right and justice demand its extinction. From such fanatical, heroic logic there is no escape. We have seen, I said, what his actual conduct was. For thirty years and more his words supported, defended, urged on such lines of conduct. Occasionally, in his own words,

> "The cant of party, school, and sect,
> Provoked at times his honest scorn,
> And Folly, in its gray respect,
> He tossed on satire's horn." *

But he lacked humor or wit to make his satire really powerful or trenchant. His words that really did their work, the words that still tell the story of the great public movement in which he was a foremost figure, were those simple, passionate utterances that came straight from his heart.

There is room here to quote only a few. But a very few will suffice, I think, to give some taste of the quality of all. At twenty-six he wrote, for the meeting of the Anti-Slavery Society in New York, a hymn.† Here are a few stanzas:

> "When from each temple of the free,
> A nation's song ascends to Heaven,
> Most Holy Father! unto thee
> May not our humble prayer be given?
>
> "Thy children all, though hue and form
> Are varied in Thine own good will
> With Thy own holy breathings warm,
> And fashioned in Thine image still.
>
> . . . .
>
> "For broken heart, and clouded mind,
> Whereon no human mercies fall;
> O be Thy gracious love inclined,
> Who, as a Father, pitiest all.
>
> "And grant, O Father! that the time
> Of Earth's deliverance may be near,
> When every land and tongue and clime
> The message of Thy love shall hear."

* Poetical Works, Vol. II. p. 120. † Ibid., Vol. III. p. 29.

At twenty-eight, when resolutions had been adopted in Congress, forbidding the postal circulation of anti-slavery literature, he wrote a "Summons" to the North.* Here is a touch of its quality:

"Methinks from all her wild, green mountains;
From valleys where her slumbering fathers lie;
From her blue rivers and her welling fountains,
And clear, cold sky;

"From her rough coast, and isles, which hungry Ocean
Gnaws with his surges; from the fisher's skiff,
With white sail swaying to the billows' motion
Round rock and cliff;

"From the free fireside of her unbought farmer;
From her free laborer at his loom and wheel;
From the brown smith-shop, where, beneath the hammer,
Rings the red steel;

"From each and all, if God hath not forsaken
Our land, and left us to an evil choice,
Loud as the summer thunderbolt shall waken
A People's voice.

"Startling and stern! the Northern winds shall bear it
Over Potomac's to St. Mary's wave;
And buried Freedom shall awake to hear it
Within her grave."

At thirty-five he wrote the passionate address, "Massachusetts to Virginia," † concerning the seizure in Boston of one Latimer, a fugitive slave. To appreciate its stirring vigor one should read it all. But here is a bit of it:

"From Norfolk's ancient villages, from Plymouth's rocky bound
To where Nantucket feels the arms of ocean close her round;

'From rich and rural Worcester, where through the calm repose
Of cultured vales and fringing woods the gentle Nashua flows,
To where Wachuset's wintry blasts the mountain larches stir,
Swelled up to Heaven the thrilling cry of 'God save Latimer!

"And sandy Barnstable rose up, wet with the salt sea spray,
And Bristol sent her answering shout down Narragansett Bay!
Along the broad Connecticut old Hampden felt the thrill,
And the cheer of Hampshire's woodmen swept down from Holyoke Hill.

* Poetical Works, Vol. II. p. 40.

† Ibid., Vol. III. p. 80.

"The voice of Massachusetts! of her free sons and daughters,
Deep calling unto deep aloud, the sound of many waters!
Against the burden of that voice what tyrant power shall stand?
No fetters in the Bay State! No slave upon her land!"

At forty-nine, when the elections of 1856 had shown the gains of the Free Soil party, he wrote thus:

"For God be praised! New England
Takes once more her ancient place;
Again the Pilgrim's banner
Leads the vanguard of the race.

. . . .

"The Northern hills are blazing,
The Northern skies are bright;
The fair young West is turning
Her forehead to the light.

. . . .

"Push every outpost nearer,
Press hard the hostile towers!
Another Balaklava,
And the Malakoff is ours!" *

The tide was turning. Four years later came the war. Here is a bit of his first war poem:

"We see not, know not; all our way
Is night, — with Thee alone is day:
From out the torrent's troubled drift,
Above the storm our prayers we lift,
Thy will be done!"

. . . .

"Strike, Thou the Master, we thy keys,
The anthem of the destinies!
The minor of Thy loftier strain,
Our hearts shall breathe the old refrain,
Thy will be done! †

"Barbara Frietchie" ‡ every one knows, — perhaps the most instantly popular ballad of the war. "Laus Deo!" § in celebration of the constitutional abolition of slavery, is not so familiar. Every word of that should be read, too. Here are a few:

* "A Song," Poetical Works, Vol. III. p. 192.
† "Thy Will be Done," Poetical Works, Vol. III. p. 217.
‡ Poetical Works, Vol. III. p. 245. § Ibid., p. 254.

"It is done!
Clang of bell and roar of gun
Send the tidings up and down.
How the belfries rock and reel!
How the great guns, peal on peal,
Fling the joy from town to town!

. . . . . .

"Did we dare,
In our agony of prayer,
Ask for more than He has done?
When was ever His right hand
Over any time or land
Stretched as now beneath the sun?

. . . . . .

"Ring and swing,
Bells of joy! On morning's wing
Send the song of praise abroad!
With a sound of broken chains,
Tell the nations that He reigns
Who alone is Lord and God!"

These few extracts must suffice to represent the most earnest work he did for above thirty years. They show, I think, the same sincerity, the same simplicity, the same earnestness, that marked his other work. And he knew the rare happiness of complete conquest. Beginning with all the world against him, he found himself for the last twenty years of his life in a world where all were against his foes.

In view of this, there are two extracts from his writings, — one in prose and one in verse, — without which, I think, our impression of him would be seriously incomplete. For they show that he possessed the power which is perhaps the ultimate test of manly greatness, — the power of serenely recognizing the worth of men from whom for years he honestly and passionately differed. The first is a letter concerning Edward Everett.

"When the grave closed over him who added new lustre to the old and honored name of Quincy, all eyes instinctively turned to Edward Everett as the last of that venerated class of patriotic civilians who, outliving all dissent and jealousy and party prejudice, held their reputation by the secure tenure of the universal appreciation of its worth as a common treasure of the republic. It is not for me to pronounce his eulogy. . . . My secluded country life has afforded me few opportunities of personal intercourse with him, while my pronounced radicalism on the great

question which has divided popular feeling rendered our political paths widely divergent. Both of us early saw the danger which threatened the country. . . . But while he believed in the possibility of averting it by concession and compromise, I, on the contrary, as firmly believed that such a course could only strengthen and confirm what I regarded as a gigantic conspiracy against the rights and liberties, the union and the life, of the nation. . . .

"Recent events have certainly not tended to change this belief on my part; but in looking over the past, while I see little or nothing to retract in the matter of opinion, I am saddened by the reflection that, through the very intensity of my convictions, I may have done injustice to the motives of those with whom I differed. As respects Edward Everett, it seems to me that only within the last four years I have truly known him." *

Fifteen years before he wrote this letter, he had written concerning Webster's Seventh of March Speech the scathing invective which he named "Ichabod":

"So fallen! so lost! the light withdrawn
Which once he wore!
The glory from his gray hairs gone
Forevermore!

. . . .

"Let not the land once proud of him
Insult him now,
Nor brand with deeper shame the dim,
Dishonored brow.

"But let its humbled sons instead,
From sea to lake,
A long lament, as for the dead,
In sadness make.

. . . .

"Then pay the reverence of old days
To his dead fame;
Walk backward, with averted gaze,
And hide the shame!" †

Fifteen years after Edward Everett's death, and thirty years after this "Ichabod" had seen the light, Whittier wrote of Webster once more. And in his collected works he departs for once from chronology, and puts beside "Ichabod" his final poem on Webster, "The Lost Occasion":

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* Prose Works, Vol. II. p. 274 (1865).
† Poetical Works, Vol. IV. p. 62.

"Thou shouldst have lived to feel below
Thy feet Disunion's fierce upthrow;
The late-sprung mine that underlaid
Thy sad concessions vainly made.
Thou shouldst have seen from Sumter's wall
The star-flag of the Union fall,
And armed rebellion pressing on
The broken lines of Washington!
No stronger voice than thine had then
Called out the utmost might of men
To make the Union's charter free,
And strengthen law by liberty.

. . . . . .

Wise men and strong we did not lack;
But still, with memory turning back,
In the dark hours we thought of thee,
And thy lone grave beside the sea.

. . . . . .

But where thy native mountains bare
Their foreheads to diviner air,
Fit emblem of enduring fame,
One lofty summit keeps thy name.
For thee the cosmic forces did
The rearing of that pyramid,
The prescient ages shaping with
Fire, flood, and frost thy monolith.
Sunrise and sunset lay thereon
With hands of light their benison,
The stars of midnight pause to set
Their jewels in its coronet.
And evermore that mountain mass
Seems climbing from the shadowy pass
To light, as if to manifest
Thy nobler self, thy life at best!" *

Is it too much to see in these lines, not an assent, but an approach to that view of the Seventh of March Speech which some, of the younger generations, are beginning to take? that it may have been not what men thought it at the time, — a blind sacrifice of principle to self; but rather the most nobly patriotic act of a nobly patriotic career, — a deliberate sacrifice of self to the Union which, without such sacrifice, was not yet strong enough to survive?

But this is not the place for political speculation. I have tried to show Whittier as he was, extenuating nothing nor set-

* Poetical Works, Vol. IV. p. 63.

ting down aught in malice. He was, I believe, above most men, one who can stand the test. His faults are patent. One cannot read him long without forgetting them in admiration of his nobly simple merits. I have said that I believe his chance of survival better than that of any other contemporary American man of letters. I trust I have shown why. In the first place, he has recorded in a way as yet unapproached the homely beauties of New England nature. In the second, he accepted with all his heart the traditional democratic principles of equality and freedom which have always animated the people of New England. These principles he uttered in words whose simplicity goes straight to the hearts of the whole American people. Whether these principles be ultimately true or false is no concern of ours here. They are the principles which must prevail if our republic is to live. And in the verses of Whittier they are preserved to guide posterity in the words of one who was incapable of falsehood.

1893. BARRETT WENDELL.

ASSOCIATE FELLOWS.

WILLIAM FERREL.

IT is particularly fitting that our Proceedings should contain some memorial of WILLIAM FERREL, for it was in this community that he first found a broad scientific association, after a boyhood of unrecognized genius and a manhood of mental isolation. It was only at the age of forty that he found companionship with men of ability like his own, and then he was so retiring by disposition and habit that he could but slowly embrace the wider opportunities opened to him.

A memoir of Ferrel by his associate, Professor Cleveland Abbe, was read before the National Academy in April, 1892, and appended to this appreciative review of his life we find a brief autobiographical sketch prepared a few years before his death, and a list of his published writings. This memoir may be referred to for fuller information, as I shall here attempt only to emphasize certain prominent features of his character, and certain of his greater accomplishments.

In recalling the work of the four great meteorologists of our country, — Redfield and Loomis, Espy and Ferrel, — the first two of them

are seen to have been characterized by a preference for inductive methods, and the other two by a greater use of deductive methods. I do not mean to imply that any one of these able men was so unbalanced as to be illogical in his studies, and follow only one method to the exclusion of the other; but that they had natural leanings one way or the other, as most men have. The greater fund of material embodied in our modern weather maps was fitly used by Loomis, much in the same manner as Redfield had used the scattered records of storms half a century earlier; the greater accuracy of the results gained by Loomis is a measure of the greater fulness of material for investigation, rather than an indication of a difference between the two men. On the other hand, much as Espy was led to his understanding of storms through a mental invention, a theory, ingeniously based on physical laws, so Ferrel was led to a generalization concerning the circulation of the entire atmosphere from a full appreciation of the laws of motion, rather than from any acuteness of observation. The consequences deduced from his theory far outstripped the knowledge of his time and profoundly affected the further progress of the science. His earlier studies of the tides were carried on in the same way. His work always illustrated the power of the mind to conceive and combine relevant facts with a view to explaining them legitimately, yet with little recourse to direct observation or experiment for himself. It is noticeable in his autobiographical sketch that Ferrel seldom makes mention of observation or experiment as holding a significant part in his early or more mature studies. As a boy he played with geometrical problems, spending weeks together over a single one; the diagrams which he scratched on the barn door with the prong of a pitchfork were only so many convenient records of the conditions of his problems; but he tells nothing of making mechanical toys, which hold so large a place in the youth of experimental philosophers. When only fifteen years old, he struggled over the prediction of eclipses, but the facts he dealt with were supplied chiefly from Farmer's Almanacs; nor did this study seem to awaken in him a wish for means of investigation with astronomical instruments, but only a keen desire for more books.

It is sad to think how limited were his opportunities in his youth. He was born in Bedford (now Fulton) County, Pennsylvania, on January 29, 1817. When he was twelve years old, his father moved across the narrow arm of Maryland into Virginia, and there the boy went to school two winters, the schoolhouse being a rude log cabin, with oiled paper instead of glass in the windows. His last school teacher took him through arithmetic and the English grammar. He was too diffi-

dent to ask his father for money with which to buy books, — too diffident even to confess his wish for books; but he worked in harvest time, and earned enough money to buy Park's Arithmetic, in which he learned something of mensuration. He continued to buy all the books he could afford, a very few, and studied them most diligently. In winter evenings he had only firelight to read by, or sometimes a pale tallow candle; in the summer, he would study while at work in the barn, attacking and solving all the problems that the books supplied. This plain living on his father's farm was not unlike that of thousands of other boys; but his unquenchable thirst for knowledge carried him out of the narrow surroundings in which his neighbors remained. We must always sympathize with the difficulties under which Ferrel struggled in his youth, and at first thought we should wish he might have had an easier life; but who can say whether the lessons of successful endeavor against all obstacles were not essential for his later development as an original investigator? His isolation turned him towards original methods of thought; and this originality and independence mark all his later work. The few distractions in his early life must have allowed the development of the perseverance with which he worked upon anything that took his attention, never giving it up until he could make some advance in it, or until he satisfied himself that he could not do so.

At the age of twenty years, having earned some money by teaching near home, he went to Marshall College, at Mercersburg, Pennsylvania. On exhausting his funds, he went home again and taught for two years more, then going to Bethany College in Virginia, where he was graduated in 1844. This closed his education as far as instruction from others was concerned, at the age of twenty-seven. For the next fourteen years he taught school, mostly in villages in Missouri, Kentucky, and Tennessee. It must be of these lonesome years that he speaks in the closing paragraph of his autobiography: "Much of my time has been wasted, especially the earlier part of it, because, not having scientific books and scientific associations, I had often nothing on hand in which I was specially interested."

Yet it was in these lonesome years that Ferrel had the good fortune of finding a copy of Newton's "Principia" in the hands of a village storekeeper in Missouri. While in Kentucky, he sent to Philadelphia for Laplace's "Mécanique Céleste"; and when in Nashville, he came upon Airy's Essays on the "Figure of the Earth," and on "Tides and Waves." Living alone with these great leaders, he carried their work on further, and made his own impress on the study of the ocean and the atmosphere.

Not until 1853, when Ferrel was thirty-six years old, does he mention any publication of his studies; but in that year he sent his first scientific article to Gould's "Astronomical Journal," and this marks the beginning of his association with scientific men. Four years later an invitation came through Dr. Gould from Professor Winlock, then Superintendent of the Nautical Almanac, for Ferrel to take part in the computations for that work. A year was needed to close his school connections in Nashville, and in 1858 we see him settled in Cambridge, with time and opportunity to gratify his studious tastes. Our image of him at that time must be clad in simple attire. He brought with him from his isolated life many homely peculiarities. From his awkward manner, one could hardly have imagined the mental power that placed him so high above most of his fellows. A gentle diffidence still possessed him, and even several years later his timidity prevented him from reading an important article on the tides before this Academy until he had carried it to several successive meetings.

He never pressed forward his views, but let them take such place as their own value should give them. He never sought for office, but was invited to fill responsible positions in the Coast Survey and the Signal Service. In these congenial surroundings, he carried on his earlier studies of the tides and the atmospheric circulation, and thus a well deserved fame gradually grew around him.

It is Ferrel's impress on meteorology that strikes me as most extraordinary, not only from the explanations that he gave to its facts, but from the new methods that he introduced into its study. Before him no one had made any considerable mathematical analysis of the motions of the atmosphere; and it was not for a number of years after he had opened this new line of investigation that European masters of mathematics followed him in it. Ferrel began this work at Nashville, where in 1856 he saw a copy of Maury's "Physical Geography of the Sea"; a suggestive work from its collection of facts, but sadly in need of correction for its erroneous theories. As in his other studies, Ferrel did not begin here by observation of the winds, but by searching for a sufficient explanation of the facts observed by others. The story is one that should be familiar in our scientific history, for it illustrates as few others can the real quality of scientific investigation. In Ferrel's hands, meteorology was not simply a routine record of observations, not simply a vague suggestion of theories. The broadest generalizations from world-wide observations were brought into harmony with the universal laws of motion, and as a result Ferrel's theory of the atmospheric circulation left all its predecessors far behind. The more

general facts concerning the prevailing winds of the world had been accumulated and were presented with much force by Maury; and at the same time, various theories had grown up to account for the facts. These theories all had two general principles in common; first, that there must be a convectional circulation between the equator and the poles; and second, that the motions thus excited must be deflected by the earth's rotation. As commonly stated, it was understood that there must be high pressure at the poles, where the air is cold, just as there is low pressure around the equator where the air is warm; and as stated by Dove, who at the time of Ferrel's entrance into the science was its leading authority, the currents from the equator to the north pole must flow from the southwest, while the return currents from the north pole to the equator must flow from the northeast. Ferrel perceived the essential incompleteness of this view of the subject. He first showed that the prevailing explanation of the effect of the earth's rotation was incomplete, and then, applying this important element in its proper measure, he introduced the idea of a rearrangement of atmospheric pressures in consequence of convectional motions. This great principle may be followed all through Ferrel's theories of cyclones and tornadoes, as well as through his theory of the circulation of the atmosphere as a whole. Its quantitative introduction into meteorology seems to me to be Ferrel's greatest achievement.

Ferrel showed that the convectional interchange between the equator and the poles must resolve itself into two great circumpolar whirls, one in either hemisphere; that in the greater part of the whirls the currents must move eastward, the trade-wind belts being the only considerable regions of westward motion; that, in consequence of the circumpolar whirls, the expected high polar pressures must be reduced to relatively low pressures, especially in the southern hemisphere, where the disturbing effects of continental interruptions are least; and that the air thus held away from the poles must be found in the tropical belts of high pressure, then coming to be recognized as great atmospheric features. It is not too much to say that the introduction of this theory has made a new science of meteorology. Ferrel's mark is permanently imprinted upon it.

We are apt, in reviewing a step of advance like this, to imagine that it was made at a single stride; but such was certainly not the case here. The theory of atmospheric circulation grew slowly in Ferrel's mind, and several years passed before it was fully developed. During its progress, Ferrel's efforts were constantly directed towards quantitative estimates of forces and results. This feature of his work is strikingly

illustrated in his theory of tornadoes, where from beginning to end he follows out a definite sequence of processes, beginning with reasonable conditions as to the distribution of temperature and moisture, and showing in the end that these might produce the extraordinary velocities seen in tornado winds. The definite quality of this work is most reassuring, in contrast with the vague speculations commonly prevailing about these peculiar storms.

After resigning from his professorship in the Signal Service in 1886, Ferrel spent his later years peacefully with his relatives near Kansas City. He died on September 18, 1891, at Mayfield, Kansas, and was there buried.

1893. W. M. Davis.

FREDERICK AUGUSTUS GENTH.

Frederick Augustus Genth was born at Waechtersbach, Hesse Cassel, May 17, 1820. After leaving the Gymnasium at Hanau, in 1839, he studied at the University of Heidelberg, and afterward under Liebig at Giessen, then under Bunsen at Marburg. He received his Doctor's degree in 1846, and was then for three years assistant to Bunsen and Privat-Docent. As a student at Heidelberg, he at first took up the study of conchology, and published at least one paper on that subject. Later he became interested in what finally proved to be the work of his life, chemical mineralogy; and after his removal to the United States, in 1848, he quickly took a very prominent place among mineralogists. In 1846 he first studied the compounds of cobalt with ammonia, and laid the foundation for all which has been done since. In this country he again took up the subject, and with Dr. Wolcott Gibbs made an elaborate investigation, which was published in the "Smithsonian Contributions to Knowledge," Vol. IX. After a very active and busy life as an analytical chemist in Philadelphia, he became, in 1872, Professor of Chemistry and Mineralogy in the University of Pennsylvania, which place he held until 1888, when he returned to his work as a chemical expert, still keeping up, however, his active interest in his favorite study, chemical mineralogy, and continuing to publish papers on that subject almost up to the time of his death, the last appearing in January, 1893. The list of Dr. Genth's published papers is a very long one, and embraces nearly one hundred titles. Among others, it includes Reports on the Mineralogy of Pennsylvania and North Carolina. Mineralogy owes him the discovery of about twenty new species. His long and useful life terminated on

February 2, 1893. Many learned societies numbered him among their members. He was elected into the National Academy of Sciences in 1872, and was one of the four Honorary Fellows of the American Association for the Advancement of Science. He was admitted in 1875 to our own Academy.

1893. WOLCOTT GIBBS.

JOHN STRONG NEWBERRY.

JOHN STRONG NEWBERRY was descended from several of the noted families of Connecticut. Of these, three, Pitkin, Wolcott, and Newberry, contributed very largely to the conduct of affairs in Colonial times. And there are probably no two families in the United States that have produced as many men of note on the bench, in politics, and in science as have the Pitkin and Wolcott families in the male and female lines of descent.

Dr. Newberry's grandfather, General Roger Newberry, son of Captain Roger Newberry and Elizabeth Newberry, daughter of Governor Roger Wolcott, had acquired a tract of several thousand acres in Ohio. His father, Henry, removed to this land in 1824, where he founded the town of Cuyahoga Falls, and was successful in his enterprises. Dr. Newberry was born in Windsor, Connecticut, December 22, 1822, and was not two years old at the time of this removal.

Professor Newberry was one of the most eminent of the small group of American geologists whose labors span almost the last half of this century, and extend over a wide range in their science. They are — too soon we must say they were — men who, in conducting the great geological reconnoissances throughout the unknown West, or in organizing and executing State geological surveys, became broadly educated in the science which they were helping to build up. Some of them were specialists in one or more departments, but all necessarily became general geologists.

Dr. Newberry's early life was passed under conditions of affluence and intelligent refinement, leaving him free to follow his intellectual bent. Already as a boy he was deeply interested in natural science, and had become familiar with the plants and animals of his State. In collecting the fossil plants of the coal mines near his home, he laid the foundation of what became later perhaps his most important specialty. Both in college and during 1849 and 1850 in Paris he prepared himself to be a physician,

receiving his degree from Cleveland Medical College in 1848, and followed that profession for a few years. But while in the Western Reserve College, where he graduated in 1846, his natural bent and the influence of Professor Samuel St. John turned him more and more strongly toward geology; and the lectures of Brongniart in Paris had a dominating influence in turning the current of his effort into palæobotany.

After four years of practice, he abandoned medicine in 1855, and became the Geologist and Botanist of Lieutenant Williamson's expedition to Oregon and California. His report concerning this survey was published in Volume VI. of the Pacific Railroad Reports. While preparing this Report, in 1856 and 1857, Dr. Newberry was Professor of Chemistry and Natural History in the Columbian College at Washington, D. C.

In 1857 he started on the memorable expedition of Lieutenant Ives to explore the Colorado River. This expedition, which occupied the winter of 1857–58, was followed in 1859 by that to the San Juan River, in which Dr. Newberry again acted as Geologist.

While he was finishing his report on the scientific results of these two fruitful expeditions, the course of political events culminated in the outbreak of the war of the Rebellion. He entered at once into the great work of the Sanitary Commission, for which his medical training and his former position as Assistant Surgeon in the Army rendered him peculiarly qualified. He soon became the Secretary of the Western Department of the Commission. It was mainly to his capacity as an organizer and his general and medical scientific training that this important Department owed its success in promptly extending its immense contributions to the prevention and alleviation of suffering among our armies and their prisoners. In his department money and hospital supplies amounting to nearly six millions of dollars were distributed.

After the war, Dr. Newberry resumed his scientific work, and was for a time connected, as a geologist, with the Smithsonian Institution. He was chosen as one of the fifty original members when the National Academy of Sciences was established by the government.

From 1866 until his death, he filled the Chair of Geology and Palæontology in the School of Mines, Columbia College. Here he exerted a strong personal influence upon the students, impressing upon them a lasting interest in his science. It would be difficult to overrate the value of this indirect contribution to the development of our mineral industries.

In 1867 he was President of the American Association for the Advancement of Science. From 1868 until his death he was President of the Lyceum of Natural History, later the New York Academy of Sciences. He was one of the judges at the Centennial Exhibition in 1876. From 1880 to 1890 he was President of the Torrey Botanical Club. In 1884 he was appointed one of the Palæontologists of the United States Geological Survey. In 1887 he was elected an Associate Fellow of our Academy. In 1888 the Murchison Medal was awarded to him by the Geological Society of London, and the following year he was elected First Vice-President of the Geological Society of America.

In 1869, Dr. Newberry was appointed State Geologist of Ohio. To this survey he devoted his energies, both as an administrator and in the field. Aside from his own contributions to the stratigraphy of the State, a large part of the scientific value of the volumes consists in his description of the wonderful fossil Devonian and Carboniferous fishes, and the fossil plants.

He was one of the most highly esteemed members of the Century Club of New York. He was also a member of the original committee appointed by the American Association for the Advancement of Science to call together an International Geological Congress, and he was chosen as President of the Congress for its first meeting in America, at Washington, in 1891. But he was unable either to preside or to be present; the increasing overwork carried on under high pressure for half a century had already ended in paralysis. On December 7, 1892, at New Haven, after nearly two years of illness, he ended a career of great and varied usefulness to his science and to his country.

The range covered by his scientific literary activity is shown by the following classification of his publications given by Professor Fairchild.*

Geology (General)	73
" Economic	38
Palæontology, Vegetable	43
" Animal	25
Botany	7
Zoölogy	6
Physiography	6
Archæology	5
Biography	3
Miscellaneous	5
	211

* Transactions of the New York Academy of Science, Vol. XII. p. 159.

Dr. Newberry was pre-eminently the pioneer in the geology of the Far West. Intellectually thoroughly equipped in general geology, in palæontology, and palæobotany he first of all saw and interpreted the underlying facts in that great synopsis of the history of our continent. The more elaborate later surveys of the Basin of the Colorado should not overshadow the priority of his wonderful descriptions and illustrations of the great Cañons, and of his correct interpretation of their mode of formation.

His most important contributions to geological literature are in palæobotany and in ichthyic palæontology.

In his description of the fossil plants brought from China by the writer, he was the first to recognize the Jura-Triassic age of an important part of the great coal-producing formation of Asia.

His work in palæobotany extended from the Devonian to the Tertiary; and he was the dominant authority as regards the fossil fishes of American palæozoic and mesozoic times. His more important and larger works on these subjects are "Fossil Fishes and Fossil Plants of the Triassic Rocks of New Jersey and the Connecticut Valley"; "The Palæozoic Fishes of North America," published in 1889 by the United States Geological Survey as Monograph XIV.; and two unpublished memoirs, "The Flora of the Amboy Clays," and "The Later Extinct Flora of North America." His work on the remarkable Devonian Fishes, including the Dinichthys, is printed in Volumes I. and II. of the Reports of the Ohio Survey. He also wrote the Reports on Fossil Fishes for the Illinois Geological Survey.

Dr. Newberry was a geologist in the broadest sense. He kept himself fully abreast with the progress of the science. He was too broadly interested to become really great in any special department. Had he devoted all his energies to either one of his favorite departments, he could easily have attained the first rank. His death emphasizes the fact that the geologists of this order are passing away, to be replaced by specialists. Such men, who, without being specialists, have full general knowledge in all departments,—an education founded upon all the underlying sciences and nurtured by investigation in many directions,—will soon be wanting, to the great loss of the science.

Science had for him no dry facts: all were parts of a history. No one could listen to his lectures or to his conversations on geological subjects, without realizing that he had in his mind a picture in which he saw Nature at her work, and plants and animals as

living entities, in their appropriate environment. While his delivery in speaking was not free from a certain mannerism, he held his audience and imbued it with the interest which he felt for his subject.

He was ever ready to leave his work, to give freely his time to all visitors, and advice to those who sought it; and this trait endears his memory to the many pupils and others who profited by his kindness.

He was one of that very small group of American Professors who feel it to be both a duty and a pleasure to maintain a close personal relation with their students, imparting to them an influence that is more far-reaching than their lectures.

1893. RAPHAEL PUMPELLY.

WILLIAM PETIT TROWBRIDGE.

WILLIAM PETIT TROWBRIDGE was born at Strawberry Hill, near Birmingham, Oakland County, Michigan, May 25, 1828. He died suddenly of heart trouble on August 12, 1892. He was married on April 21, 1857, at Savannah, Georgia, to Miss Lucy Parkman. His wife, three sons, and three daughters survive him.

He graduated at the head of his class from the United States Military Academy at West Point in 1848, and during his last year there he acted as Assistant Professor of Chemistry, although he was only nineteen years old. After graduation he became Second Lieutenant of the Engineer Corps, and was ordered to West Point as assistant in the Astronomical Observatory, where he served two years, till 1850. He was then ordered, at his own request, to duty on the Coast Survey, where he remained until 1856, winning his first lieutenancy in 1854. His work on the Coast Survey was as follows. He worked at first upon the triangulation of the coast of Maine, which was placed in his charge in 1852; he also worked along the Appomattox River below Petersburg, and the James River below Richmond, in Virginia, and a part of the time along the Pacific slope; this last occupying him from 1853 to 1856. While in Virginia, he urged the importance of constructing the Dutch Gap Canal, which was actually accomplished during the civil war.

His work on the Pacific slope was tidal and magnetic as well as geodetic, and covered a length of coast of over 1,300 miles. His tidal gauges recorded the earthquake waves emanating from Simoda, Japan, December 23, 1854, two months before information of the oc-

currence reached this country by steamer. In 1856 he left the Coast Survey, and became Professor of Mathematics in the University of Michigan; but in 1857 he returned to the Coast Survey as Scientific Secretary, residing in Washington, D. C., retaining this position till 1862. Before the civil war he established the first permanent observatory in this country for the automatic registration of magnetic variations at Key West, and also prepared for publication the results of the exploration of the Gulf Stream. At the beginning of the war he was called upon to prepare a minute description of the harbors, inlets, and rivers of the southern coast, from Delaware Bay to Galveston; and also to determine whether Narragansett Bay would be a suitable location for a navy yard station, or not.

During the rest of the war he had charge of the branch office of the War Department in New York City, and acted as agent in the supply of material, and as constructor of local fortifications. He built the forts at Willett's Point and on Governor's Island, and made the repairs of Fort Schuyler.

From 1865 to 1871 he was Vice-President of the Novelty Iron Works, New York, of which Mr. Horatio Allen was President. The latter had been the first to introduce the locomotive in America, in 1829. He had also designed the early American locomotives run in South Carolina, and the Novelty Works had designed and constructed the first Transatlantic steamers of the Collins line; and during the civil war they had a great deal to do in the construction and alteration of vessels and machinery. During his connection with these works he carried out a series of experiments to determine the water consumption per horse power per hour of a series of steam-engines at different points of cut-off. These experiments were among the earliest of their kind, and led the practice of engine builders for years.

From 1871 to May, 1877, Mr. Trowbridge was Professor of Dynamic Engineering in the Sheffield Scientific School of Yale College, where he built up his new department, and planned and constructed the new Sheffield Hall in which the engineering instruction is given.

From 1877 until his death, in 1892, he held the Professorship of Engineering in Columbia College, New York. There were added to the courses as they existed before his incumbency, successively, courses in thermodynamics, dynamics of machinery, and water supply engineering, while the engineering courses already existing were enormously developed. In this he was aided by Professors F. R. Hutton and H. S. Monroe.

While at the Novelty Iron Works he designed a cantilever bridge for the East River at Blackwell's Island, and a company was formed in 1869–70 to carry out the project, but the panic of 1873 put an end to all efforts to build it. While at the Sheffield School, he designed a coil boiler, intended to incorporate the most advanced ideas of forced circulation of water, automatic supply of feed water from a magazine, and self-feeding of fuel. Its manufacture was turned over to a company. He also gave much thought to deep-sea sounding. He was a member of the Century Club; was Adjutant General of Connecticut from 1870 to 1876; commissioner for building a bridge across the Quinnipiac River from 1870 to 1876; commissioner for building the Capitol at Hartford from 1873 to 1878; commissioner for establishing harbor lines at New Haven from 1872 to 1878; and he was also one of the three commissioners appointed by Governor Cornell to examine the State Capitol at Albany.

He was a member of the New York Academy of Sciences, of the American Society of Mechanical Engineers, an Associate Fellow of the American Academy of Arts and Sciences, and also of the National Academy of Sciences.

He received the degree of A. M. from Rochester University in 1856, and from Yale in 1870; of Ph. D. from Princeton in 1880; and that of LL. D. from Trinity in 1882, and from Michigan University in 1887. In 1880 he was at the head of the Department of Power and Machinery for the Tenth Census. The treatise which he published on Heat and Steam is well known among engineers.

The following is a list of his works in the United States Coast and Geodetic Survey Reports: —

1851. Triangulation, Maine.
1852. Triangulation, Maine. Triangulation, Appomattox River.
1853. Triangulation, James River. Tides of the Western Coast.
1854. Tidal and Magnetic Observations. Eclipse Observations.
1855. Tidal and Magnetic Observations. Earthquake Waves. Description of Bodega Bay.
1856. Tides, Hudson River.
1857. Wind Observations.
1858. Office Work. Law of Descent of Weight in Deep-sea Soundings Comparative Cost and Progress of Geodetic Surveys. Cost and Progress of Coast Survey Work.
1859. Researches. Deep-sea Sounding Apparatus.
1860. Gulf Stream Examinations. Report on Magnetic Station at Key West.
1861. Hydrography, Bristol Bay. Report on Sounding Apparatus.
1874. Magnetic Observations at Key West between 1860 and 1866.

While possessing great professional ability, and profound technical knowledge, he was a very genial and also a very conscientious and modest man, and one who won the admiration and regard of all who came in contact with him.

In closing, I must make my acknowledgments to Professor F. R. Hutton, who has kindly furnished me with most of the facts from which to compose this short paper.

1893. GAETANO LANZA.

GEORGE VASEY.

GEORGE VASEY, for many years Chief Botanist in the Department of Agriculture, died at his home in Washington, March 4, 1893. His illness was of brief duration, and although he had attained an advanced age, he was until several days before his death exceptionally regular in performing the arduous and time-consuming duties of his position. His work entailed a wide correspondence, and it was thus that many botanists throughout the country and abroad came to appreciate his kind assistance. His letters, however, were chiefly of a professional nature, and many of his colleagues knew little or nothing of his personal history.

Born near Scarborough, England, February 28, 1822, he was brought in early childhood by his parents to Western New York, where the family settled at Oriskany, Oneida County, not far from the birthplace of Asa Gray. George Vasey, being one of a large family in humble circumstances, received only a meagre schooling, and at the age of twelve began work in a store. He early became interested in the plants of the region, and derived his first botanical knowledge of them from Mrs. Lincoln's Botany, a little volume of quaint diction, now almost forgotten. So anxious was he to possess this work, that, not being able to buy it, he copied the text entire. His botanical interest soon attracted the attention of Dr. Knieskern, who brought him to the notice of Professors Torrey and Gray. Having begun the study of medicine at the age of twenty-one, and having been graduated from the Berkshire Medical Institute at Pittsfield, Massachusetts, in 1846, Dr. Vasey removed in 1848 to Illinois, where he spent eighteen years in the practice of medicine, chiefly at Ringwood and Elgin. Here he had an excellent opportunity to observe the rich prairie vegetation, and made extensive collections, which have a high historic value, since they show the native flora before it had been so greatly impaired and displaced by the present exhaustive cultiva-

tion of the prairie lands and drainage of the numerous and extensive marshes. During his residence in Illinois, Dr. Vasey was influential in encouraging scientific observation, and in organizing the Illinois Natural History Society, of which he was made first President. He certainly did as much as any one to make Illinois botanically one of the best known States of the Union.

In 1868, partly from scientific interests, partly for financial reasons, he accepted the position of Botanist upon Major Powell's Colorado Expedition. Soon after his return to Illinois he was made Curator of the Natural History Museum of the State Normal University. April 1, 1872, he was appointed Chief Botanist of the Department of Agriculture, and Curator of the National Herbarium under the Smithsonian Institution. At that time the national botanical collections consisted largely of copious but little organized material, which had been brought in by numerous official surveys and exploring expeditions. This material was of the highest value, containing hundreds of types; but the immense labor of sorting and identifying it can only be appreciated by those who have had practical experience in herbarium work. The present rich and well organized government herbaria form accordingly the best memorial of Dr. Vasey's untiring efforts and wise administration. Not only has he greatly developed these collections and the libraries connected with them, but by securing an able corps of assistants has much increased the importance and value of the regular botanical publications of the government. A complete list of his own numerous and useful contributions to American Botany has recently been published,* so that only their general character need here be indicated. His earlier writings were mostly short articles upon various botanical subjects published in the "American Entomologist and Botanist," of which he was at one time associate editor. With his appointment in the Department of Agriculture his facilities for research were much increased, and his publications became more copious and important. Owing to the high agricultural importance of the Grasses, he concentrated his attention more and more upon this group of plants, studying not only their obscure systematic relations, but their economic qualities as well. Most important among his papers upon this Order are his bulletin upon the Agricultural Grasses of the United States, published in 1884, and his Illustrations of North American Grasses, a part of which was still in press at the time of his death.

* Botanical Gazette, XVIII. 176.

Dr. Vasey was twice married, and was exceptionally happy in his domestic life. He leaves a family of six children. His personal manner was singularly gentle, and even his purely professional acquaintances early recognized his warmth of heart and kindly disposition. In the autumn before his death he represented the Smithsonian Institution at the International Congress of Botanists in Genoa, where he was made one of the Vice-Presidents.

1893. B. L. ROBINSON.

FOREIGN HONORARY MEMBERS.

SIR WILLIAM BOWMAN.

SIR WILLIAM BOWMAN, Baronet, of London, England, Fellow of the Royal Society, — one of the most distinguished of the Foreign Honorary Members of the Academy, — was born at Nantwich, England, in 1816. His father devoted much of his leisure to studies in natural history; and the son inherited this taste, and the habit of minute and careful observation which marked each step of his career, impressing the stamp of exactitude upon all his researches and conclusions. While a pupil at the Birmingham Hospital, at seventeen years of age, he wrote several monographs of much merit, one of which, "On Affections of the Larynx," published with colored illustrations, was received with great favor, and is still regarded as a very valuable production. His whole life fulfilled its early promise in intelligent and discriminating research; and he well knew how to discern and interpret what was of value as a positive addition to science, and a means for its further advancement.

At twenty-three years of age we find him Demonstrator of Anatomy at King's College Hospital in London, where he devoted himself to minute researches as to the finer structures of the human system, and to histological teaching, especially that kind of histology which is imperatively necessary to the understanding of function.

The following year he visited the hospitals of Paris, and of Austria, Germany, and Holland. On his return he was appointed the Assistant, and became afterwards the successor, of the distinguished investigator, Dr. Todd, with the title of Professor of

Physiology and of General and Morbid Anatomy. Their joint published treatise on Physiology was for a long period the textbook for instruction in that science.

Even at this early age, Bowman's enthusiasm, accuracy, and thoroughness had earned for him recognition as a leader in scientific research; and in 1842 he was awarded the high distinction of the gold medal of the Royal Society for his discoveries in science.

The next year he read before the British Association at Oxford a paper on "Some Points in the Anatomy of the Eye, chiefly in reference to its Powers of Adjustment." This earliest and supremely important contribution to our knowledge of the anatomy and physiology of the ciliary muscle within the eyeball, which plays so essential a part in the focal adaptation of the eye to various distances, constituting the function of accommodation, —and, together with his published "Researches on the Structure and Functions of the Eye," added immensely to our resources for the relief of disabilities of the organ of vision, — through which we learn the major part of what goes to make up the sum of human knowledge, and by the help of which we discharge most of the duties, and enjoy a large part of the pleasures, of human existence.

In 1846 Bowman was appointed Assistant Surgeon, and in 1851 became Surgeon of the Royal Ophthalmic Hospital at Moorfields, London, and later its Consulting Surgeon.

The invention of the ophthalmoscope by Helmholtz, in 1851, opened a new era for ophthalmoscopy. The wonderful disclosures gained through the aid of this new instrument for illuminating and exploring the interior of the eyeball — in which we may now well say, "There is nothing hid which cannot be revealed" — were early brought to Bowman's notice by Professors Donders and Von Graefe, then on a visit to England; and this trio of ardent devotees of ophthalmological science enthusiastically shared in eager observations and researches as to the normal conditions and morbid changes in the interior structures of the human eye, now for the first time revealed to human view.

Another important sequel of this visit was the publication soon afterwards at London, by the Sydenham Society, of Professor Donders's elaborate, most accurate, and exhaustive treatise "On the Refraction and Accommodation of the Eye," dedicated,

as a well merited tribute, to Bowman, "Whose merits in the advancement of Physiology and Ophthalmology are equally recognized and honored in every country."

Bowman's pre-eminent talent was worthily acknowledged in the conferring upon him of the honorary degrees of M. D. and LL. D. by several of the Universities of the United Kingdom, by his election as Fellow and as Vice President of the Royal Society, by the bestowal of a Baronetcy by the Queen, and by his enrolment as Honorary Fellow by many foreign scientific bodies.

Sir James Paget, also one of our Honorary Associates, says of Bowman: "His method of scientific work was not materially changed when he may have seemed to have narrowed his field of study; — for his practice and all his writings showed, not only that he applied a wide range of general knowledge in the study of his special subject, but he made his special knowledge applicable in illustrating general principles. He maintained a high standard of professional conduct, and never swerved from what he believed to be right."

Sir William was by no means one of whom it could be said, "*Knowledge* comes but *Wisdom* lingers." What he learned, he well knew how to adapt to the best uses. He was no less remarkable for his practical good sense, and his just estimation of other men and of new methods, than he was for his untiring industry and his sagacity in research. And all this was accomplished amidst the imperious claims of active hospital service and a very extensive private and consulting practice. His relations with other scientific observers striving to do good work, and with those of the profession seeking his counsel in important cases, were marked by kindly sympathy, encouragement, and help. The laurels he had so nobly won were unostentatiously worn.

Letters from him received by me but a short time before his death mentioned his gradual retirement from active duties, but gave no hint of mental decline, and were full of cheerful reminiscences. His decease occurred on March 27, 1892, after a brief illness from pneumonia, at his country residence, Joldwynds, near Dorking, England.

1893. HENRY WILLARD WILLIAMS.

ALPHONSE DE CANDOLLE.

ALPHONSE LOUIS PIERRE PYRAMUS DE CANDOLLE, born in Paris, 27 October, 1806, a son of the botanist, Augustin Pyrame de Candolle, was for sixty years a prominent figure in the botanical world, and with hardly any perceptible diminution of his mental powers, having reached an age which made him one of the oldest of living botanists, he died at Geneva, 4 April, 1893, leaving a son to represent the third generation of botanists in this remarkable family. His early life was passed at Montpellier, where his father was Professor until the family removed to Geneva. In 1825 he began the study of law at Geneva, taking his degree in 1829. From 1831 he assisted his father in his duties as Professor of Botany, and in 1835 he succeeded him in that position, which he held until 1850 when he retired to private life, his ample private fortune enabling him to devote himself to botany. In 1832 he was married to Mlle. Jeanne Kunkler, who died forty-five years later. The greater part of his married life was passed in Geneva in the winter, and at his country-house in Vallon in the suburbs of that city in the summer; but during the last few years of his life he did not leave the house on the Cour Saint-Pierre, well known to all botanists as containing the great herbarium founded by his father.

One is naturally tempted to compare the botanical work of Alphonse de Candolle with that of his father, under whose guidance he was trained; but in fact no comparison is possible, for the characteristics of their scientific work were very different, and their natural tastes were quite dissimilar. The elder De Candolle was one of the masters of descriptive botany. In 1826 he commenced the publication of the *Prodromus*, a work planned on a vast scale to include descriptions of all known plants, of which seven volumes had already appeared previous to his death, in 1841. Although the name of Alphonse de Candolle was associated with that of his father in the *Prodromus*, he had no real fondness for descriptive work, being more interested in other botanical subjects. It should not be understood, however, that, even if his tastes were not in this special direction, his descriptive work was not excellent. On the contrary, his first paper, *Monographie des Campanulacées*, published in 1831, was not only admirable from a taxonomic point of view, but was also valuable for the notes on plant distribution, a subject which he was destined to treat more fully at a later day. On the death of his father, De Candolle took charge

of the continuation of the *Prodromus*, until, on the completion of the Dicotyledons in the seventeenth volume, issued in 1873, it was necessarily abandoned, not from indifference on his part, but because, owing to the rapid increase of collections and explorations in recent times, the field had become too great for a single work on the original plan of the *Prodromus*. In nothing are the moral and intellectual qualities of De Candolle better seen than in his management of the *Prodromus*. To a certain extent, sacrificing his individual preferences to a sense of filial duty, he devoted himself to the completion of the great work planned by his father, sparing neither thought nor money. Although the working up of the numerous orders was, of necessity, entrusted to specialists, too much cannot be said in praise of his good judgment in supervising the whole and of his constant courtesy towards and just appreciation of other botanists, which enabled him to secure the willing aid of experts when necessary. Although the *Prodromus*, as a distinct work, came to an end with the completion of the seventeenth volume, Alphonse de Candolle, assisted by his son Casimir, began in 1878 a series of *Monographiæ Phanerogamarum*, to include some orders not treated in the *Prodromus*, and revisions of certain of the orders contained in its earlier volumes.

The great work of De Candolle was his *Géographie Botanique Raisonnée*, which appeared in 1855. In this he displayed at their best the qualities which marked him as a great botanist in a field in which he was not overshadowed by the greater reputation of his father, as had been the case in his earlier writings. It is probable that the writings of Humboldt had first attracted him to the study of the distribution of plants. In the *Géographie* is clearly seen the legal quality predominating in his mind. This may in part be attributed to his early professional studies but it is not unlikely that it was to a great extent inborn. He brought together an immense number of facts, arranged them with great skill, and reviewed them collectively with a clear, unpartisan criticism worthy of a judge on the bench. He had such a talent for collecting statistics, and using them with discretion, that, had he not been brought up as a botanist, we might almost suppose that he would have been a political economist. In estimating the value of the *Géographie* we should not forget that it was published four years before the appearance of Darwin's "Origin of Species." Bearing this in mind, we cannot fail to recognize the great superiority of this work over previous works on distribution.

The position assumed by De Candolle in his *Géographie* can be expressed best in the following condensed translation of his own words: —

"The principal facts of geology and palæontology suffice to explain the facts of botanical geography, or at least to indicate the nature of the explanation, which it requires the progress of many sciences to complete. The most numerous, the most important, and often the most anomalous facts in the existing distribution of plants, are explained by the operation of causes anterior to those now in operation, or by the joint operation of these and of still more ancient causes, sometimes of such as are primitive. The geographical and physical operations of our own epoch play but a secondary part. The only phenomena explainable by existing circumstances are: 1st, the limitation of species, and consequently of genera and families, in every country where they now appear; 2d, the distribution of the individuals of a species in the country it inhabits; 3d, the geographical origin and extension of cultivated species; 4th, the naturalization of species and the opposite phenomenon of their increasing rarity; 5th, the disappearance of species contemporaneous with man. . . .

"In all this we observe proofs of the greater influence of primitive causes, and of those anterior to our epoch; but the growing activity of man is daily effacing these, and it is no small advantage of our progressing civilization that it enables us to collect a multitude of facts of which our successors will have no visible and tangible proof."

De Candolle did not make the least pretence of attempting to explain the origin of species, but limited himself to the question of distribution. The causes of the present distribution involve ultimately, of course, the question as to their origin, but the immediate question which De Candolle desired to discuss was simply, What are the existing facts regarding distribution, and in what direction do those facts point? The *Géographie* is a storehouse of facts which is still of very great value to students of distribution, and it is to be regarded as a merit of De Candolle's work that he attempted to point out clearly what could be explained by present conditions, as distinguished from the more extended question of what must necessarily be referred to past ages for solution. He, among other points, insisted that in estimating the effect of climate we must consider, not the mean temperatures, but the mean temperatures during the growing season, or those above the freezing point. The question of the origin of cultivated plants, which formed a part of the *Géographie*, was again treated in detail by De Candolle in his *Origine des Plantes Cultivées*, 1883, a work involving not only great botanical knowledge, but also prolonged archæological study, and which is regarded by experts as a classic on the subject.

The evolutionary writings of Darwin had their effect on the later

work of De Candolle. In his *Histoire des Sciences et des Savants* he attempted in his favorite statistical manner to trace, if possible, the direct inheritance of talent for scientific studies. Assuming that the leaders of science would naturally be elected members of learned societies, he compared the family names to be found in the lists of members of certain societies, and came to the general conclusion that by inheritance it was not so much marked special talents which were acquired, as what we may call general intellectual force, so that the sons of distinguished men are on the whole as likely to reach distinction in different fields of science from those in which their fathers were distinguished, as they were to attain prominence in the same fields. It has however been objected, with more or less justice, to data from the membership in learned societies, that such membership, although presumably a recognition of ability, is not always so, and that an allowance must be made for favoritism, and other human failings, from which even members of learned societies are not exempt.

The principles which should guide botanists in describing plants, or, if we may be allowed to use the expression, the literary technique of systematic botany, was a subject in which De Candolle was much interested, and what he wrote on this topic was always marked by clearness and suggestiveness. His sound common sense enabled him to distinguish at once what was accurate and practical, from what was vague and visionary. Probably no botanist was ever consulted so frequently as he on the general principles of plant nomenclature, and none was ever more discreet and urbane in the discussion of this delicate question. His *Phytographie*, 1880, was an admirable treatise, expounding the general principles and traditions of nomenclature in a most sensible way, entirely devoid of personal feeling or partisanship, a work most refreshing to read at the present day, when one is surfeited with the multitude of writings on the subject written from a purely theoretical point of view, without regard to practical possibilities, and in a spirit of the most narrow intolerance. De Candolle's authority in taxonomical matters was universally recognized, and at the request of the committee of organization of the International Botanical Congress held at Paris in 1867, he prepared the *Lois de la Nomenclature Botanique* which was to serve as a basis for the discussion on disputed points of nomenclature. Together with the historical introduction and commentary presented to the Congress, they are generally known as De Candolle's Laws, and still serve as the basis for all discussions on nomenclature. He published subsequently other papers discussing some of the disputed points of nomen-

clature, and in all cases his candid, judicial statement of the questions appears all the more admirable when compared with the ill-natured and personal presentation of objections by some of his opponents.

De Candolle can hardly be said to have been a voluminous writer, although he was a frequent contributor to the different scientific proceedings and journals, especially the *Archives des Sciences Physiques et Naturelles* of Geneva. His style was easy and fluent, but although, as has been said, his method of study was statistical, his writings are neither dry nor tedious. He did not limit himself by any means to botany, but often discussed social and economical subjects, for, like his father, he considered that a good citizen should not shut himself up in the limits of his scientific studies, but should take an interest in all questions of public interest. One of his most generally interesting works is the volume of *Mélanges*, a series of essays on different subjects. Of his scattered papers, that which was most widely known, especially in English-speaking countries, was *La Langue Dominante*. In that paper he discussed the adaptabilities of different languages to the needs of modern civilized life, and he advanced the opinion that English, with its comparatively simple declensions and conjugations, with its facility for forming compound words and its abundance of short exclamatory expressions, was likely to become the universal language of the future. This agreeable prophecy, while it naturally found favor among English peoples, was regarded by some others as an expression of what they considered his prejudice for England and the English. That he had a genuine admiration for the English was shown in several ways, but his feeling was not so one-sided as to deserve the name of prejudice.

De Candolle was tall in stature, with a prominent nose, and small, rather deep-set eyes. His appearance was strikingly dignified, but it was not a freezing dignity, for his manners were polished and courteous, and he had the happy faculty of making all, no matter how different their ages or conditions, feel perfectly at ease in his presence. In conversation he was fluent and interesting, and he possessed that greatest of talents in a good talker, the power of drawing out what was interesting and instructive in others. Probably no botanist of recent times was more widely known personally, or more deservedly respected. Botanists from both hemispheres visited him in the family mansion at Geneva opposite the old cathedral, and he always took pleasure in showing the many treasures of books and plants which had been accumulated by his father and himself. He was untiring in his efforts to supply to correspondents any information in his power,

and he made no distinction between contemporary or well known botanists and the young or obscure. Many of the younger generation of botanists remember his kind words of encouragement and sympathy and are grateful for his criticisms, which were always made in a kindly spirit, without cynicism or ill-nature. His long and active life came gradually to a close, without physical suffering or mental decrepitude. It was the privilege of the writer to meet him in his library surrounded by his books only a few months before his death, and, although he had become somewhat deaf, it was hard to believe that he was so far up in the eighties, for he showed the same intelligence and the same interest in what was going on in the botanical world as he had shown twenty years before.

A list of the botanical writings of Alphonse de Candolle will be found in the *Revue Générale de Botanique*, Volume V., pages 200–208.

1893. W. G. FARLOW.

AUGUST WILHELM VON HOFMANN.

AUGUST WILHELM HOFMANN, a Foreign Honorary Member of the Academy, was born in Giessen, April 8, 1818. His childhood passed quietly in his native place, and in its schools he was fitted for its University, at that time famous for the laboratory which Liebig had established in the old guard-house, and in which chemistry was first taught by experiment. It is not strange, therefore, that, after paying attention for a short time to other studies, Hofmann was attracted to chemistry and entered the laboratory. Here he soon became one of the most eminent among that company of students, including the picked men from all civilized countries, as his first researches, which related to the identity of aniline obtained from different sources, showed a grasp of the subject, a chemical insight, and a skill in experiment remarkable in so young a man. He also had the good fortune in the course of them to discover the chloranilines, the formation of which could not be brought into harmony with the dualistic theory then at the height of its dominion, and this brought his work prominently to the notice of the chemical world.

In 1840 Liebig took him as his private assistant, when it became his duty to do part of the editorial work on the "Annalen der Chemie und Pharmacie"; and this early literary training undoubtedly was a principal cause of the ease with which he

handled his pen in later years. He stayed in Giessen until the spring of 1845, and all this time his intimacy with Liebig was growing closer and closer; he worked with him in the laboratory during the week, and frequently accompanied him on Sunday excursions or vacation journeys. To the end of his life he could not speak with too much affection and gratitude of his great teacher.

From Giessen he went to Bonn to lecture on agricultural chemistry, but before the year was out accepted a call to the directorship of the Royal College of Chemistry, which was to be founded in London after the plan of Liebig's laboratory at Giessen; and in October, 1845, he opened the laboratory of this institution, where he remained for twenty years.

There could be no better proof of Hofmann's ability and force of character than his success in this position, the difficulties of which were enormous. It was necessary to establish a laboratory, and organize a course of chemical instruction, at a time when the details of experimental teaching of chemistry had been only partially worked out, and this was to be done by a German suddenly plunged among Englishmen, with whose national feelings he must bring himself into harmony so as to adapt his plans to the environment; and, what was harder still, it was necessary that these plans should satisfy the subscribers on whom the venture rested for support. After the successful launching of the enterprise, during which he invented many of the methods of laboratory teaching since in common use, he was further embarrassed by a loss of interest on the part of these subscribers, whom it was necessary to arouse and recruit by a series of popular lectures, and to conciliate by doing technical work for many of them without charge. At the same time his own means were very slender. I well remember the humor with which he told a story of lighting the gas accidentally with a five-pound note at this period, and feeling an ache in his bones from it for a week. Later, however, thanks principally to his discoveries among the aniline dyes, this evil was remedied, so that he was never again in want of money, and the Royal College of Chemistry, after he had steered it successfully through these troubled waters, was put on a solid basis as a state institution under another name.

In addition to the duties already mentioned, he was frequently required to give scientific advice to the government, and served

on the jury at most of the great exhibitions. He was also a prominent member of the London Chemical Society,—Foreign Secretary as early as 1847, and President in 1861; in 1856 he was appointed Master of the Mint. With these varied activities and the numerous distractions caused by the brilliant scientific society of London at this time, it is surprising that he should have produced a very large volume of scientific work of the highest quality; but the riddle is solved by his statement that he often worked in the laboratory till two or three o'clock in the morning, and in this way succeeded in getting through an amount of work which would have broken down a man with a less robust constitution.

After twenty years of this life, in spite of its pleasures and honors, he began to turn his eyes toward Germany again, and at first intended to go to Bonn, where the laboratory was built under his direction; but before leaving London to take charge of it, his destination was changed by a call to Berlin, where he became Professor in 1865, and at once set to work with his accustomed energy to reorganize the chemical department of the university, which had fallen into some disorder, and to build the large laboratory, which was finished in 1869. The site was chosen so that the laboratory could be connected with a house which had been for many years the property of the Prussian Academy, and was used as the dwelling of both its chemist and astronomer, until the astronomer was removed to other quarters shortly before Hofmann's arrival, and the chemist of the Academy left in undisputed possession; to this post Hofmann succeeded in virtue of his appointment as Professor of Chemistry in the Berlin University, and here the last years of his life were passed in happy activity.

In term time he gave three lectures a week, each lasting two hours, —a severe tax on the strength of any man, especially in the hot, close weather of a Berlin July. Then he went into the laboratory and visited his private assistants, of whom he sometimes had as many as six, and his advanced students. This filled the morning. The afternoon was devoted to work in his private laboratory, or a second visit to his students; and in the evening, after supper between half-past eight and ten, he passed a short time with his family, and then at about eleven settled down to work in his study till from one to three in the morning. As in London, he added to his regular work a great many other occu-

pations. He was the father of the German Chemical Society, founded in 1867, which under his care has grown to such enormous proportions. His services as a juror at the great exhibitions were still in frequent demand, and he issued an elaborate report on the chemistry in that of Vienna, which amounted to a full statement of the condition of technical chemistry in the year 1873. In his literary work a large place is filled by his historical accounts of the earlier chemists and the alchemists of Berlin, and also by numerous obituaries of his distinguished contemporaries, many of which toward the end of his life he collected into three large interesting volumes. To these should be added his "Introduction to Modern Chemistry, Experimental and Theoretic," a short text-book brought out at the beginning of his life in Berlin, which gave a remarkably clear account of what were at that time the new theories, illustrated by ingenious and novel lecture experiments. His brilliancy as a lecturer led to his giving many public lectures, notably the Faraday Lecture of the London Chemical Society in 1875, — a life of Liebig, which was afterward published in book form.

He did not seek for honors, and frequently expressed the slight value he set upon titles, but they came to him unsought. At the beginning of 1875 he received the honorary title of Privy Councillor (*Geheimrath*), and in 1890 he was ennobled.

In his vacations he was a great traveller. There was hardly a country of Europe which he had not visited, and in the summer of 1883 he travelled over most of the United States, when his eager interest in all that he saw, and his delighted appreciation of American humor, left pleasant memories to those who were fortunate enough to meet him.

The busy life which I have described, continued with only one serious interruption from sickness (in 1878), until he was seventy-four years old, when the end came suddenly on the 5th of May, 1892. He had just begun to lecture again with his accustomed energy, after his return from a short vacation journey, when on coming home from a faculty meeting he began to feel unwell, and in half an hour was dead, — a fortunate end to a happy life.

My first sight of Hofmann was characteristic of the man; it was in the chemical lecture-room, just after the academic quarter of an hour had ended. He came hurrying in, wearing a white knit scarf about his throat, and a tall hat. With what

seemed to be a single motion, he took them off and laid them on the table; then plunged into his lecture, rather quietly at first, but gathering energy as he went on, until he carried all along with him in the rush of his ideas. Not that he talked very fast, but his lecture seemed like a broad rapid stream, flowing with irresistible force. When he grew excited, he had a curious gesture, apparently taking the words from his mouth and throwing them at his audience with the whole strength of his body. His style was clear, vivid, and picturesque, his experiments striking and apt, since he had a rare faculty for contriving them, and was usually most successful in carrying them through; but if, as rarely happened, an experiment did not go well, or an assistant was slow in his work, he would fairly dance with impatience.

In the laboratory it was much the same. In his tall hat and the invariable knit scarf, he hurried up to a student, and called out almost as soon as he was within hearing, "What have you got to show me to-day?" Then, if the new substance crystallized well, — "This is a beautiful substance, a superb substance. We will make a couple of experiments with it." After which came a host of watch-glass experiments, leading deep into the subject, all done with the same dash and enthusiasm. But if the student had not enough clean watch-glasses, or did not answer his questions quickly enough, he in his impatience shook his knees with a peculiar sideways motion, — a most alarming gesture, which also greeted the man who had not looked up all that had been done on his subject, and did not have his knowledge at his fingers' ends. This mode of teaching was terrible for shy, nervous men; but for others it was wonderfully inspiring, and all his students realized that this impatience was only the overflow of his superabundant energy, and in no way allied to bad temper. He was, in fact, one of the kindest of men, and took the strongest personal interest in his students, adopting their successes or failures in the laboratory as his own; and when they were in misfortune he was always ready with his help, whether in advice, sympathy, or money, as I have the best reason to know.

The energy which charaterized his teaching also appeared in his researches. A rough count shows that at least three hundred and fifty-eight papers bear his name; but even this number does not give a just idea of his productiveness, since probably

as many, or even more, papers were published by his students under their own names, and these in most cases were as much his work, except so far as mere manual labor was concerned, as those included in the number given above.

A general direction was given to Hofmann's work by his first research in Liebig's laboratory, which consisted in proving the identity of three substances, — benzidam from nitrobenzol, and aniline and krystalline obtained in different ways from indigo. He also showed that this substance (aniline) was contained in the mixture of bases extracted from coal tar by Runge, and called by him kyanol. This called his attention to the compounds of nitrogen, and in this class of bodies his most important discoveries have been made. First among these must be placed his work upon the aniline dyes, on account of the great industry to which it has given birth; for although he had many competitors in this field, and was not the first to introduce an aniline color into commerce, his discoveries are so fundamental and various that he can be justly called the father of this industry. This work grew naturally from his first research just mentioned, since rosaniline, the most important of these dyes, is easily made by the oxidation of crude aniline. This substance was first satisfactorily investigated by him, although it had been obtained earlier by others, and he brought our knowledge of it into such a state that it could be manufactured on a commercial scale. From this rosaniline (magenta dye) he soon showed that different colors could be obtained by replacing part of its hydrogen by other radicals; and in this way he made violets and blues of a brilliancy unknown before, which, with a vivid green that soon followed, at once came into general use. It may be added, that an investigation made under his direction laid the foundations for preparing aniline itself on an industrial scale. This work dates from his London period, and some idea of the excitement of that time can be gained from the fact that he reported the results of his analysis of aniline blue to the French Academy by telegraph, probably the only time that a paper has been communicated in this way.

Another discovery of his, although not yet of technical value, is even more important to chemists than the work just mentioned. This is the method of preparing the amines by the action of ammonia on alkyliodides or bromides, which alone would have been sufficient to make him great, as by it not only

were three of the most important classes of chemical compounds discovered, — the secondary and tertiary amines, and the substituted ammoniums, — but also this discovery had a great, an almost decisive influence on the adoption of the present chemical theories. This was one of his earliest researches, and it is interesting to note that in the later years of his life he added still another way of preparing primary amines to the meagre list of known methods; it was by the action of bromine and water upon the amides, and has rendered these very expensive substances more accessible.

Another discovery, the displacement by heat of hydrocarbons from substituted ammonic hydrates, dates also from his later years, and promises to be of the first importance, since it has already done much, and will do more, to solve the perplexing riddle of the constitution of the natural alkaloids.

Of his other important discoveries I shall not attempt to speak in detail; they include syntheses of the mustard oils and guanidine, with the working out of the constitution of these products of life; the migration of alkyl radicals from nitrogen to carbon under the influence of heat, an interesting observation which has been of great value in the color industry; and researches on the isonitriles, cedriret, orthoamidomercaptans, cyanuric acid, the ethylene bases, and many other substances natural and artificial. And here should also be mentioned the new forms of apparatus contrived by him, especially that for determining vapor densities, and the eudiometers and other pieces of lecture apparatus to which I have alluded earlier.

In the preceding description of the man and his work I have tried to portray his vigorous, enthusiastic energy, and his exceeding kindliness, which also appeared in his family life, making him at the same time a most affectionate and ambitious father. His wonderful inventiveness and intellectual power also have been sufficiently shown by the account of his discoveries, and his great administrative ability by his success in organizing and carrying on the large chemical laboratories of London and Berlin. The picture of Hofmann would be incomplete, however, without mention of his breadth of character. He always deplored the unfortunate quarrel between German and French chemists, which followed the Franco-Prussian war, and through it all kept up the most friendly relations with the leaders of French chemistry. An even better proof of this

absence of all littleness in him is found in the fact that he would receive information or take corrections even from his students, saying, "I am willing to learn from any one."

He was simple and temperate in his habits of life, and fond of innocent jokes and amusements. He had a remarkable faculty for languages. On one occasion, at an international chemical dinner, he made speeches in five languages, — German, English, French, Italian, and Spanish. In person he was of middle height, with an extraordinary depth of chest, and a figure massive rather than either large or stout. His forehead was high, crowned with waving hair, and in his earlier days he wore a mustache and small pointed beard, afterwards replaced by a full beard.

He has left very tender and affectionate memories in the hearts of a multitude of students, who will remember their chemical father as long as they live; and when all of these are gone, his works will still stand, his enduring monument.

1893. CHARLES LORING JACKSON.

SIR RICHARD OWEN.

WHEN SIR RICHARD OWEN died, full of years and honors, on December 18, 1892, the last prominent representative of the old school of comparative anatomists passed away. For about fifty-six of his eighty-eight years he was actively devoted to the science which he loved so well and served so truly. Born at Lancaster on July 20, 1804, he took his medical diploma at the Royal College of Surgeons in 1822, and began the practice of medicine. His dissections when a student had attracted the notice of Abernethy, who procured for him the work of cataloguing the preparations of the Hunterian Museum in 1828. The consequences of this appointment were momentous both for him and for science. It brought him into the intimacy of a relative of John Hunter, Mr. Clift, who was then the chief Curator. Owen married his daughter, and thus naturally, as it were, became the follower of the renowned founder of the Museum. Hunter's mantle could not have fallen on worthier shoulders. It is easy to conceive that an office so attractive to an anatomist boded no good to his success as a practitioner. In a few years he withdrew from the profession he had first chosen, to devote himself wholly to science. In

1830 he read a paper on the Ourang before the new committee on science of the Zoölogical Society, which marked the beginning of the scientific activity of that Society. At the age of thirty he was made a Fellow of the Royal Society; and in 1834 he had the signal honor of being chosen the first Hunterian Professor at the Royal College of Surgeons. He held this position till 1856, when he was appointed Superintendent of the Natural History Department of the British Museum. Here he found himself confronted with the great difficulty which has baffled so many curators before and since, — wan of space. We cannot go into the history of his arduous struggle for what he felt was necessary; suffice it to say, it is largely to him that the collection of Natural History of the British Museum owes its magnificent new home at South Kensington. He resigned this position at wellnigh fourscore years, in 1883. Though he retired early from the practice of medicine, he served more than once or twice on boards dealing with sanitary questions. He was on the commission to inquire into the health of towns in 1843 and in 1846. He wrote a special report on the condition of his native town, Lancaster, in 1848. He was on the Board of Health of the metropolis in 1846 and 1848. This is by no means the full list of his services of this nature. When one remembers the vast amount of original research he was always engaged in, his mental activity seems indeed phenomenal. From the beginning of his writing with, if we mistake not, the first instalment of the "Catalogue of the Hunterian Museum," in 1830, catalogue, book, and memoir followed one another in constant succession. His writings did not wholly cease even with his final retirement from office. The range of his studies was enormous. In 1832 appeared his memoir on the "Pearly Nautilus," and in 1885 was completed his "History of the British Reptiles," in three volumes. His researches were not confined to organisms visible to the naked eye. He was the first to put in its proper place the Trichina Spiralis. Among his more important works may be mentioned his "Odontography," "The Archetype and Homologies of the Vertebrate Skeleton," and his "Comparative Anatomy of Vertebrates."

Wonderful has been the progress in science during the long period of Owen's activity. Perhaps even more wonderful is the entire change of lines of thought and of methods of study since the promulgation of the Darwinian hypothesis. This event

occurred when Owen was passing out of middle age. It is no wonder that he looked at the matter conservatively. In the early days of the theory it was not so clear as now that all evolution is not Darwinism. Many evolutionists would now hesitate to say that he was wrong. The tendency of earlier and cruder evolution was to throw utterly aside all respect for such works as that on the "Archetype." Indeed, the extravagances of visionaries like Oken had paved the way for a reaction. Professor Owen was essentially a devout man. He saw in nature plan and law, and through these the Creator. He wrote as follows in the Preface to his Comparative Anatomy: "In the second aim, the parts and organs, severally the subjects of these chapters, are exemplified by instances selected with a view to guide or help to the power of apprehending the unity which underlies the diversity of animal structures; to show in these structures the evidence of a predetermining Will, producing them in reference to a final purpose; and to indicate the direction and degrees in which organization, in subserving such Will, rises from the general to the particular." In spite of his singleness of purpose Owen's strong point was neither in controversy nor in philosophy. He excelled in his powers of observation and in his capacity for work. Theories and systems may rise and fall, but his descriptions of living and extinct forms may remain the standard of instruction for generations.

1893. THOMAS DWIGHT.

ALFRED, LORD TENNYSON.

ALFRED, LORD TENNYSON, a Foreign Honorary Member of the Academy in Class III., Section 4, since 1876, died at Aldworth in Surrey on the 6th of October, 1892.

Alfred Tennyson was born at Somersby Rectory in Lincolnshire on the 6th of August, 1809, the son of the Reverend George Clayton Tennyson. He early showed a love of poetry, and when little more than eighteen years old found a publisher for a volume of poems written in connection with his brother. This poetic flight was promptly followed by others, including, in 1829, a college prize poem on the subject of Timbuctoo. These early poems are smooth and pleasant, good-boyish verses, far better than most productions of the kind.

In 1830 appeared "Poems, chiefly Lyrical," — a volume con-

taining, among other pieces, "Claribel," "Mariana," "The Deserted House," and "The Sleeping Beauty"; the last of these was afterwards expanded. In the same year Tennyson and his friend Arthur Hallam made an expedition into Spain, carrying money and letters written in invisible ink to some Spanish rebels, with whom they were in sympathy. In 1832 another volume was published, made up, like its predecessor, of short poems, among which were "The Lady of Shalott," "The Miller's Daughter," "Œnone," "The May Queen," and "The Lotos-Eaters." By these pieces Tennyson established his position as a poet. Indeed, he hardly rose higher in lyric sweetness at any later time than he did in the exquisite songs "It is the miller's daughter," and "Love that hath us in the net."

On the 15th of September, 1833, Arthur Hallam died at Vienna. The grief of the poet for the loss of his friend was very great, and was aggravated by the fact that Hallam was to have married Tennyson's sister. Such sorrows might be thought too sacred to be laid open to the world by any biographer; and Tennyson has pronounced

> "Shakespeare's curse on clown and knave
> Who will not let his ashes rest!"

But he has himself chosen to impart to the public a share in this grief; he has embalmed it in noble verse; and his verse, unlike his ashes, is the property of the world. At the time of its occurrence the blow seems to have stunned him. For nearly nine years he published little; only a few pieces in fugitive publications. In 1842, however, a new edition of his poems appeared in two volumes, including all those poems in the previous editions which he cared to retain, and adding many new ones, among which were "Locksley Hall," "St. Simeon Stylites," "Lady Clare," "The Two Voices," "The Lord of Burleigh," "Sir Galahad," and "Break, break, break."

Five years later came "The Princess," but without its lyrics, which were published with the third edition of the poem in 1850. This latter year was one of great importance in Tennyson's life. It is marked by the publication of "In Memoriam," by his marriage, and by his appointment as poet laureate. The fine "Ode on the Death of the Duke of Wellington" appeared in 1852, to be followed, in 1854, by "The Charge of the Light Brigade," a thousand copies of which were printed on a broad-

side, and distributed to the soldiers before Sebastopol. In 1855 "Maud" was published. In 1859 the first collection of "Idylls of the King" was brought out, — "Enid," "Vivien," "Elaine," and "Guinevere." They had been preceded, many years earlier, by the "Morte d'Arthur," and were followed after an interval of ten years by "The Coming of Arthur," "The Holy Grail," and "Pelleas and Ettare"; then by "The Last Tournament"; and finally, in 1885, by "Balin and Balan." All the Idylls have been arranged to form a sequence.

It was not until 1876, when the poet was in his sixty-seventh year, that his first tragedy, "Queen Mary," was presented. It was followed at intervals by other dramas. In 1880, a volume of "Ballads" appeared, including "The Defence of Lucknow," "The Voyage of Maeldune," and many other poems.

In 1884 Tennyson was made a peer, with the title of Baron Aldworth and Farringford. The honor was well bestowed. There have been British poets as great as this one whose elevation to the peerage would have been incongruous: imagine a Lord Wordsworth, or a Lord Burns. But Tennyson, throughout his writings, moves with a stately dignity and grace. His verse is sonorous and refined. In spite of a curious fondness for expressing despair, he never tears a passion to tatters. His robes shine with a score of colors; they are set with a hundred jewels; they flow in liquid lines, and never get out of order. He seldom attempts to wear homespun, and when he does try it on, it does not fit him. Such a poet is well suited to take his recognized place in a great aristocracy.

The work of Tennyson divides itself naturally into periods and into forms. The style and substance, nearly uniform throughout, run readily into various moulds. That style, as I have said, is dignified, lofty, and sonorous. From these qualities it seldom departs and never to its advantage. Like many essentially dignified men, Alfred Tennyson liked to be playful; but his playfulness seldom raises a smile to the lips of his readers. When he is pathetic, we sorrow with him; when he is inclined to jest, we generally wish he would refrain. An exception may perhaps be made in favor of some of the pieces in dialect, where the humor is of the very quietest description. Occasionally, and most in the earlier poems, there are great lapses from good taste; but in his better pieces this is very rare, and, after all, it is only good taste, and not morals or feelings, that suffer. Yet

the shock may be great. The reader is interested; he is moved; the force of poetry has mastered him; every pore of his mind is open to the magic sunlight. Suddenly he is struck by a chilling blast which raises the mental goose-flesh. I will give but one instance of this, for the fault, as I have said, is not common in Tennyson's best pieces; but it is too characteristic to pass entirely unnoticed. Let the reader give up his mind to the first ten lines of the following quotation from the "The Miller's Daughter":

> " But when at last I dared to speak,
> The lanes, you know, were white with may,
> Your ripe lips moved not, but your cheek
> Flashed like the coming of the day;
> And so it was — half-sly, half-shy,
> You would, and would not, little one!
> Although I pleaded tenderly,
> And you and I were all alone.
>
> " And slowly was my mother brought
> To yield consent to my desire :
> *She wished me happy, but she thought*
> *I might have looked a little higher.*"

But such accidents as this are of rare occurrence. Generally the poem will flow on, with an even cadence to the ear and a well ordered sequence to the mind, rising grandly, sinking gracefully, best when most serious and tender.

The substance of the poems varies more than the style. It is now religious or philosophical, now patriotic; again it is of love or of nature. It is always pure, generally hopeful and believing.

> " There lives more faith in honest doubt,
> Believe me, than in half the creeds,"

writes Tennyson; and his sympathies are chiefly reserved for those doubts which are full of faith. The son of a clergyman, and born in 1809, — at the height of the reaction against the incredulity of the eighteenth century, — he was a convinced and unwavering Christian; liberal with the liberality of a large mind and especially with the charity of a loving heart; faithful to the faith of his childhood. He is full of hope, too. We feel that his deepest despair is an affair of temper and digestion, that the strong heart of the man and his inmost convictions are

healthy and sunny. In his worst moods he never sneers — but at a mob, or a Frenchman. His patriotism is intense and unquestioning. Had we to judge from the internal evidence of his poems, we might believe that he had never strayed from English ground. His imagination has never travelled elsewhere, save for those little excursions with the classic muse which the Cambridge or Oxford man absolutely owes to his schoolmasters. If, in reading him, we are startled by an echo of Dante, or even of Walt Whitman, it is but a faint and distant echo, soon dying away. In England Tennyson was at home, and none of her sons have loved her more nobly. Every flower of the English field, every cloud of the English sky, had its word for him. And like his patriotism is his purity of heart,—a positive quality, elevating the whole nature of the man, the whole work of the poet.

There are three distinctly marked periods in Tennyson's poetical life. The first includes his early poems, and ends with the two volumes issued in 1842, at the close of the long time of comparative silence that followed the death of Arthur Hallam. The poetry of this period is chiefly lyrical, consisting of ballads with a slight thread of narrative running through them, like "The Lady of Shalott," "Œnone," "The May Queen," or "A Dream of Fair Women"; or of songs entirely without story, such as "It is the miller's daughter." Occasionally in this period a hint was given of the forms which the poet's genius was to take in the future. Thus the "Morte d'Arthur" gives promise of the "Idylls": "The Two Voices" is a prelude to "In Memoriam." The poetry of this earlier part of the poet's life is often exquisite; the lyrics are nearly, if not quite, as good as his best. Indeed, "Love that hath us in the net," and "Break, break, break," are among the very best things in that line that he ever accomplished, — among the sweetest songs in the English language. Yet if Alfred Tennyson had died in 1845, he would not have ranked among the greatest of British poets. His place would have been with Campbell and not with Scott, with Moore and not with Byron. He was not destined to leap, like Keats and Shelley, to the first rank while under thirty. It was in the second period of his life, in the strength of his manhood, that Tennyson achieved the height of his greatness. In the twelve years from 1847 to 1859 appeared "The Princess" and its lyrics, "In Memoriam," and the first collection of

Idylls; and these are the most characteristic and the finest of his poems. It is on them that his reputation must finally rest.

In 1859 Tennyson was fifty years old. He had become a thorough master of his art. Many of his best qualities remained to him; he was still the maker of graceful and sonorous verse, but he was not destined to add to his already towering reputation. In his later years he worked faithfully and successfully in his old forms, and tried a new one, the dramatic. He retained much of the vigor and sweetness of his mind; he gave to the English-speaking world much good poetry, and with it very little that his warmest admirers should regret.

Of the forms of poetry, that to which Tennyson adhered through life was the lyrical, with a touch of narrative,—from "Mariana in the Moated Grange," at the beginning, to "Charity," at the end of his works. In this line he was very successful, but it is a line which hardly admits the highest poetry. We are all fond of "The May Queen," and "Lady Clare," and "The Beggar Maid,"—men of fifty know them by heart; but we do not place them beside "Lycidas," or Portia's speech in court, or Wordsworth's sonnets, or the best passages of "In Memoriam." Yet we are grateful to the poet who gives us so much pure enjoyment. The poems written officially, as laureate, often belong to this category. They are strong and stirring, almost the best that has been done in that manner. The "Ode on the Death of the Duke of Wellington" is the most poetical, but is too long to catch the popular ear. The "Welcome" to the Princess of Wales on her marriage contains lines not easily forgotten:—

> "Sea-kings' daughter from over the sea, Alexandra!
> Saxon and Norman and Dane are we,
> But all of us Danes in our welcome of thee, Alexandra!"

"The Charge of the Light Brigade" thunders through the head, and will hold a place in the British memory but little below Campbell's "Mariners of England" and Burns's "Scots wha hae."

There is another style of lyric in which Tennyson has surpassed his achievement either in narrative or in official song. The poems written in this style are purely lyrical, appealing to no extraneous emotion, seeking their interest neither in a story, nor in a description of scenery, nor in a mood of patriotic

emotion. There are not a dozen of them of the best class in all his works, in spite of the attempts of the poet to add to their number; and, with perhaps two exceptions, they belong to the period of his greatest poetic power. On them his fame as a great lyric poet will chiefly rest. These poems are "Love that hath us in the net," and perhaps, "It is the miller's daughter," written long before the others, "Break, break, break," first published in 1842, and five or six songs in "The Princess." Let us, for the sake of comparison, recall a lyric poem of either category, and, first, one deriving a part of its interest from narration and description. We may choose "Sir Launcelot and Queen Guinevere," which is perhaps less familiar than some others, although full of beautiful poetry:

"Like souls that balance joy and pain,
With tears and smiles from heaven again
The maiden Spring upon the plain
Came in a sun-lit fall of rain.
In crystal vapor everywhere
Blue isles of heaven laughed between,
And far, in forest deeps unseen,
The topmost elm-tree gathered green
From draughts of balmy air.

"Sometimes the linnet piped his song:
Sometimes the throstle whistled strong:
Sometimes the sparhawk, wheeled along,
Hushed all the groves from fear of wrong:
By grassy capes with fuller sound
In curves the yellowing river ran,
And drooping chestnut-buds began
To spread into the perfect fan,
Above the teeming ground.

"Then, in the boyhood of the year,
Sir Launcelot and Queen Guinevere
Rode thro' the coverts of the deer,
With blissful treble ringing clear.
She seemed a part of joyous Spring:
A gown of grass-green silk she wore,
Buckled with golden clasps before;
A light-green tuft of plumes she bore
Closed in a golden ring.

"Now on some twisted ivy-net,
Now by some tinkling rivulet,

In mosses mixt with violet
Her cream-white mule his pastern set:
  And fleeter now she skimmed the plains
Than she whose elfin prancer springs
By night to eery warblings,
When all the glimmering moorland rings
  With jingling bridle-reins.

"As she fled fast thro' sun and shade,
The happy winds upon her play'd,
Blowing the ringlet from the braid:
She looked so lovely, as she sway'd
  The rein with dainty finger-tips,
A man had given all other bliss,
And all his worldly worth for this,
To waste his whole heart in one kiss
  Upon her perfect lips."

Compare with this the Lullaby from "The Princess," which derives no interest from narrative, but appeals simply to the ear and the poetic sense:

"Sweet and low, sweet and low,
  Wind of the western sea,
Low, low, breathe and blow,
  Wind of the western sea!
Over the rolling waters go,
Come from the dying moon, and blow,
  Blow him again to me:
While my little one, while my pretty one, sleeps.

"Sleep and rest, sleep and rest,
  Father will come to thee soon;
Rest, rest, on mother's breast,
  Father will come to thee soon;
Father will come to his babe in the nest,
Silver sails all out of the west
  Under the silver moon;
Sleep, my little one, sleep, my pretty one, sleep."

From the lyrics we pass to an even more important part of Tennyson's work, to what our fathers might have called "Poems of Sentiment and Reflection," to the embodiment of the poet's social, political, and religious ideas, to his philosophy of life. Alfred Tennyson was generous in his aspirations for humanity, he was a liberal in the best sense, a devout Christian, a natural optimist. He believed in progress, with a faith never really

extinguished, although sometimes clouded, and the progress in which he believed was of the true kind. Let us listen to a few lines from "In Memoriam":

"Who loves not Knowledge? Who shall rail
Against her beauty? May she mix
With men and prosper! Who shall fix
Her pillars? Let her work prevail.

. . . . .

"A higher hand must make her mild,
If all be not in vain; and guide
Her footsteps, moving side by side
With wisdom, like the younger child:

"For she is earthly of the mind,
But wisdom heavenly of the soul.
O friend, who camest to thy goal
So early, leaving me behind,

"I would the great world grew like thee,
Who grewest not alone in power
And knowledge, but by year and hour
In reverence and in charity."

It is the soundness and sweetness of the poet's nature which make the greatness of "In Memoriam," — a dirge of inordinate length, written in a stanza which is at first a little repellent to the ear. In spite of these drawbacks, it is well to read the whole poem at a sitting, and to mark passages for future reference. For the poem has a unity of design, and carries the reader with the poet through the depths of self-contained and dignified sorrow to the clear heights of consolation which is not forgetfulness.

And as Tennyson is hopeful in matters of religious faith, so is he in things social and political. He rails at the crowd, sometimes a little unreasonably, but he trusts to the future of the race.

"He seems to hear a Heavenly Friend,
And through thick veils to apprehend
A labour working to an end."

And this faith never left our poet long. It is good to know that after the confusion of "Locksley Hall Sixty Years after" came the serenity of "Akbar's Dream," the consciousness that the light of our century is "dawn, not day."

It is not necessary to linger over "The Princess," although there are many charming lines in the poem, beside those of the

lyrics that are set in it. "The Princess" is somewhat marred by the attempt of the poet to be light; "Maud," on the other hand, which contains much exquisite poetry, is injured by its despairing theme. Tennyson loved despair as one loves a foreign country, without ever being quite at home in it. He was eminently self-commanding, and violent passion has in his mouth a literary sound which is fatal to its appearance of genuineness. Let anybody who would compare the serious optimist and the laughing pessimist read Tennyson's "Locksley Hall," or "Maud" with its artificial darkness, and then turn to the translation which Tennyson's friend Fitzgerald has made of the poem of Omar Khayyam, with its sad humor and stern questioning of Providence. It is neither "Maud" nor "The Princess" which first rises to the mind when Tennyson's longer poems are mentioned. He is perhaps best known as the writer of the "Idylls of the King."

The legends of King Arthur had long interested the poet. Among his earlier poems, "The Lady of Shalott," "Sir Galahad," and "Sir Launcelot and Queen Guinevere" had found a place, calling on him for some of his best work. And in the "Morte d'Arthur" he had gone farther, and actually written a part of the great series which was to be one of the principal achievements of his best years. The Idylls, as we now possess them, form a continuous poem, which has for its theme the rise, the adventures, and the fall of Arthur, the mythical King of Britain, and of the knights whom he collected in his order of the Round Table. The interest and the style of the poem are wonderfully sustained, in view of the fact that an interval of more than forty years elapsed between the appearance of the earliest and that of the last written cantos. The present arrangement of the parts of the poem is not that of their composition; but the story, as completed, marches firmly and smoothly from the Dedication to Prince Albert and "The Coming of Arthur" at the beginning, to "The Passing of Arthur" and the Ode to the Queen at the close. The stately measure moves steadily along, and scenes of beauty open on every hand. We are in England, but in an England glittering with the brilliance of chivalry, and lighted by the glow of fairy-land. Here is no rush, no turmoil, no grime and sweat; wounds and death are but glorious accidents; even sin has lost its grossness. Adultery is one of the themes of the tale, yet no coarse word is spoken, no low idea suggested; the poet's imagi-

nation is so pure that nothing can be foul in its neighborhood. Tennyson hates unchastity so thoroughly and honestly that he tells of it chastely.

Is the poem as great a triumph of art as it is of morals? Yes and no. The Idylls are very readable, from their scenery and from their smoothness. We are glad to be in an enchanted world. As for the characters, they interest us less. The blameless Arthur never seems quite real; he is rather a bundle of good qualities than a man of flesh and blood. If we turn from him to recall another chivalrous saint, one who really walked this earth, — if Joinville tells us of his royal master, Saint Louis, — we feel that we have a true saint and a living man before us; that Joinville has really loved his hero and comrade. Did Tennyson really love King Arthur, week-days and all? Lancelot and Tristram, and the rest, are somewhat shadowy. Queen Guinevere, although often referred to, appears but little, and generally not to advantage. Enid, that patient Grizzel, charming in her courtship, hardly obtains in her persecution by her brutal husband the sympathy which she labors so hard to deserve. Vivien is a bad woman, and Tennyson could no more describe a bad woman than Fra Angelico could have painted one. Only "Elaine the fair, Elaine the lovable, Elaine the lily maid of Astolat," wins us with her beauty, and melts us with her hapless love. It is to her sorrows, and to the repentance of Guinevere, and to the death of Arthur, that the poet's best powers are given. In describing these the verse is more than smooth and stately; it is poetry of a high order.

It was not until his seventh decade was well advanced that Tennyson took to writing dramas. The attempt was unfortunate. There was nothing dramatic in his genius or in his training. He was not strong in imagination of plot, in conception of character, or in invention of situations. Moreover, a bad tradition of the British stage calls for funny scenes in a tragedy, and Tennyson was never so doleful as when he wanted to be funny. The best to be expected in his tragedies was fine lines, and fine lines do occur in them from time to time, although less often than in any other of his poems.

What is to be the permanent place of Tennyson in English literature? The poet sings first to his own age, he lives with its life, he burns with its passions, he interprets it to itself, and it repays him with enthusiastic affection. Such is the feeling of

men now in middle life for Alfred Tennyson. Later generations have different problems to solve, or have to answer the old riddles propounded in new forms. Knowledge, wisdom, and poetry have to be expressed again from time to time to suit new demands. Therefore all poets (unless preserved by some fortunate accident, like Milton, the mouthpiece of a great religious party, or Burns, the especial poet of a small and distinct nation) have to go through a time of retirement. We all know that Shakespeare himself was once thought to be a simple-minded and obsolete person. The greatest of his successors could speak patronizingly of his "native wood-notes wild." As the clothes of our fathers seem to us merely ridiculous, while those of the last century appear picturesque, so the poets that delighted our grandfathers are too often foolish and contemptible in our ears, while those of the age of Elizabeth or of Charles charm us by their quaintness. We reject the affectations of Moore to delight in those of Herbert. From the period of oblivion thus created, the minor poets hardly emerge at all. A page or two in a volume of collected verses, a couple of songs in an anthology, — such are the claims to immortality of Sidney and Wither, of Lovelace and Suckling. The great poets come out with their literary baggage much reduced. From such a time of oblivion Dryden and Pope are just emerging. In its depths are Scott and Byron. To Wordsworth has fallen the singular fortune that his voice has been most clearly recognized by a generation subsequent, but not long subsequent, to his own. It may be that he will prove an exception, and that he will live and drop his Idiot Boys, and silly old men, and most of his Prelude and Excursion, keeping his noble sonnets and the best of his lyrics without a dormant time. But Tennyson seems likely to share the common fate, and its coming will probably not be long delayed; for he is a poet of the early part and the middle of this century, whose life was prolonged to extreme old age, but who learned nothing very new after fifty, any more than the rest of us do. What is likely to be his place when, in a future age, the lover of poetry collects on his shelves the best volumes of English verse? What will the "Abridged Works of Lord Tennyson" contain? A perfect answer to such a question cannot be given, but I think we may approach it. The volume will not be a small one. There will be in it many ballads and short pieces, some of them treating of classical subjects, like

"Tithonus" and the "Lotos-Eaters," more with their scene laid on English ground. There will be a few exquisite lyrics. There will be several selections from "In Memoriam," and a passage or two from "Maud." There will be the "Idylls of the King," a good deal abridged. Of how many great poets of old days is a larger proportion familiar to cultivated people?

What, then, is the place of Tennyson? Not with the very few giants whose names we breathe with loving awe, — Æschylus, Dante, Shakespeare; but with the great English poets who have made our literature the only one to be mentioned beside the Greek, — with Chaucer and Spenser, with Dryden and Pope, with Byron and Scott and Burns and Wordsworth and Shelley. In such glorious company we may believe that Tennyson has his place.

1893. EDWARD J. LOWELL.

The Academy has received an accession of twenty-three Resident Fellows, eleven Associate Fellows, and seven Foreign Honorary Members.

The Roll of the Academy, corrected to date, includes the names of 191 Fellows, 95 Associate Fellows, and 73 Foreign Honorary Members.

MAY 10, 1893.

LIST

OF THE

FELLOWS AND FOREIGN HONORARY MEMBERS.

(Corrected to October, 1893.)

RESIDENT FELLOWS.—190.

(Number limited to two hundred.)

Class I.—*Mathematical and Physical Sciences.*—69.

Section I.—7.

Mathematics.

Benj. A. Gould,	Cambridge.
Gustavus Hay,	Boston.
Benjamin O. Peirce,	Cambridge.
John D. Runkle,	Brookline.
T. H. Safford,	Williamstown.
William E. Story,	Worcester.
Henry Taber,	Worcester.

Section II.—10.

Practical Astronomy and Geodesy.

Solon I. Bailey,	Cambridge.
Seth C. Chandler,	Cambridge.
Alvan G. Clark,	Cambridgeport.
J. Rayner Edmands,	Cambridge.
Henry Mitchell,	Boston.
Edward C. Pickering,	Cambridge.
John Ritchie, Jr.,	Boston.
Edwin F. Sawyer,	Brighton.
Arthur Searle,	Cambridge.
O. C. Wendell,	Cambridge.

Section III.—40.

Physics and Chemistry.

A. Graham Bell,	Washington.
Clarence J. Blake,	Boston.
Francis Blake,	Weston.
John H. Blake,	Boston.
Samuel Cabot,	Brookline.
Arthur M. Comey,	Somerville
Josiah P. Cooke,	Cambridge.
Charles R. Cross,	Boston.
Amos E. Dolbear,	Somerville.
Thos. M. Drown,	Boston.
Charles W. Eliot,	Cambridge.
Thomas Gaffield,	Boston.
Wolcott Gibbs,	Newport, R. I.
Edwin H. Hall,	Cambridge.
Henry B. Hill,	Cambridge.
Silas W. Holman,	Boston.
William L. Hooper,	Somerville.
Henry M. Howe,	Boston.
Charles L. Jackson,	Cambridge.
William W. Jacques,	Newton.
Alonzo S. Kimball,	Worcester.

Leonard P. Kinnicutt,	Worcester.
William R. Livermore,	Boston.
Charles F. Mabery,	Cleveland.
A. A. Michelson,	Worcester.
George D. Moore,	Worcester.
Charles E. Munroe,	Washington.
John U. Nef,	Chicago, Ill.
Robert H. Richards,	Boston.
Theodore W. Richards,	Cambridge.
Edward S. Ritchie,	Newton.
A. Lawrence Rotch,	Boston.
Charles R. Sanger,	Cambridge.
Stephen P. Sharples,	Cambridge.
Francis H. Storer,	Boston.
Elihu Thomson,	Lynn.
John Trowbridge,	Cambridge.
Harold Whiting,	Cambridge.
Charles H. Wing,	Ledger, N. C.
Edward S. Wood,	Cambridge.

SECTION IV. — 12.

Technology and Engineering.

Eliot C. Clarke,	Boston.
Gaetano Lanza,	Boston.
E. D. Leavitt,	Cambridgeport.
Hiram F. Mills,	Lawrence.
Cecil H. Peabody,	Boston.
Alfred P. Rockwell,	Boston.
Andrew H. Russell,	Boston.
Peter Schwamb,	Arlington.
Charles S. Storrow,	Boston.
George F. Swain,	Boston.
William Watson,	Boston.
Morrill Wyman,	Cambridge.

CLASS II. — *Natural and Physiological Sciences.* — 57.

SECTION I. — 11.

Geology, Mineralogy, and Physics of the Globe.

Thomas T. Bouvé,	Boston.
H. Helm Clayton,	Milton.
Algernon Coolidge,	Boston.
William O. Crosby,	Boston.
William M. Davis,	Cambridge.
O. W. Huntington,	Cambridge.
Jules Marcou,	Cambridge.
William H. Niles,	Cambridge.
John E. Pillsbury,	Boston.
Nathaniel S. Shaler,	Cambridge.
Warren Upham,	Somerville.

SECTION II. — 9.

Botany.

William G. Farlow,	Cambridge.
Charles E. Faxon,	Boston.
George L. Goodale,	Cambridge.
H. H. Hunnewell,	Wellesley.
Benj. L. Robinson,	Cambridge.
Charles S. Sargent,	Brookline.
Arthur B. Seymour,	Cambridge.
Charles J. Sprague,	Boston.
Roland Thaxter,	Cambridge.

SECTION III. — 19.

Zoölogy and Physiology.

Alex. E. R. Agassiz,	Cambridge.
Robert Amory,	Boston.
James M. Barnard,	Milton.
Henry P. Bowditch,	Boston.
Wm. Brewster,	Cambridge.
Louis Cabot,	Brookline.
Harold C. Ernst,	Boston.
J. Walter Fewkes,	Boston.
Edw. G. Gardiner,	Boston.
Samuel Henshaw,	Cambridge.
Alpheus Hyatt,	Cambridge.
Theodore Lyman,	Brookline.
Edward L. Mark,	Cambridge.
Charles S. Minot,	Boston.
Edward S. Morse,	Salem.
James J. Putnam,	Boston.
Samuel H. Scudder,	Cambridge.
William T. Sedgwick,	Boston.
James C. White,	Boston.

Section IV. — 18.

Medicine and Surgery.

Samuel L. Abbot,	Boston.
Edward H. Bradford,	Boston.
Arthur T. Cabot,	Boston.
David W. Cheever,	Boston.
Benjamin E. Cotting,	Roxbury.
Frank W. Draper,	Boston.
Thomas Dwight,	Boston.
Reginald H. Fitz,	Boston.
Charles F. Folsom,	Boston.
Richard M. Hodges,	Boston.
Oliver W. Holmes,	Boston.
Frederick I. Knight,	Boston.
Francis Minot,	Boston.
Samuel J. Mixter,	Boston.
Wm. L. Richardson,	Boston.
Henry P. Walcott,	Cambridge.
John C. Warren,	Boston.
Henry W. Williams,	Boston.

Class III. — *Moral and Political Sciences.* — 64.

Section I. — 10.

Philosophy and Jurisprudence.

James B. Ames,	Cambridge.
Charles C. Everett,	Cambridge.
Horace Gray,	Boston.
John C. Gray,	Boston.
Nathaniel Holmes,	Cambridge.
John E. Hudson,	Boston.
John Lowell,	Newton.
Henry W. Paine,	Cambridge.
Josiah Royce,	Cambridge.
James B. Thayer,	Cambridge.

Section II. — 20.

Philology and Archæology.

William S. Appleton,	Boston.
Charles P. Bowditch,	Boston.
Lucien Carr,	Cambridge.
Franklin Carter,	Williamstown.
Joseph T. Clarke,	Boston.
Henry G. Denny,	Boston.
Epes S. Dixwell,	Cambridge.
William Everett,	Quincy.
William W. Goodwin,	Cambridge.
Henry W. Haynes,	Boston.
Bennett H. Nash,	Boston.
Frederick W. Putnam,	Cambridge.
Edward Robinson,	Boston.
F. B. Stephenson,	Boston.
Joseph H. Thayer,	Cambridge.
Crawford H. Toy,	Cambridge.
John W. White,	Cambridge.
Justin Winsor,	Cambridge.
John H. Wright,	Cambridge.
Edward J. Young,	Waltham.

Section III. — 21.

Political Economy and History.

Charles F. Adams,	Quincy.
Edward Atkinson,	Boston.
Edmund H. Bennett,	Boston.
Mellen Chamberlain,	Chelsea.
John Cummings,	Woburn.
Andrew M. Davis,	Cambridge.
Charles F. Dunbar,	Cambridge.
Samuel Eliot,	Boston.
A. C. Goodell, Jr.,	Salem.
Henry C. Lodge,	Nahant.
Augustus Lowell,	Boston.
Edward J. Lowell,	Boston.
Silas M. Macvane,	Cambridge.
Francis Parkman,	Boston.
John C. Ropes,	Boston.
Denman W. Ross,	Cambridge.
Charles C. Smith,	Boston.
F. W. Taussig,	Cambridge.
Henry W. Torrey,	Cambridge.
Francis A. Walker,	Boston.
Robert C. Winthrop,	Boston.

Leonard P. Kinnicutt,	Worcester.
William R. Livermore,	Boston.
Charles F. Mabery,	Cleveland.
A. A. Michelson,	Worcester.
George D. Moore,	Worcester.
Charles E. Munroe,	Washington.
John U. Nef,	Chicago, Ill.
Robert H. Richards,	Boston.
Theodore W. Richards,	Cambridge.
Edward S. Ritchie,	Newton.
A. Lawrence Rotch,	Boston.
Charles R. Sanger,	Cambridge.
Stephen P. Sharples,	Cambridge.
Francis H. Storer,	Boston.
Elihu Thomson,	Lynn.
John Trowbridge,	Cambridge.
Harold Whiting,	Cambridge.
Charles H. Wing,	Ledger, N. C.
Edward S. Wood,	Cambridge.

SECTION IV. — 12.

Technology and Engineering.

Eliot C. Clarke,	Boston.
Gaetano Lanza,	Boston.
E. D. Leavitt,	Cambridgeport.
Hiram F. Mills,	Lawrence.
Cecil H. Peabody,	Boston.
Alfred P. Rockwell,	Boston.
Andrew H. Russell,	Boston.
Peter Schwamb,	Arlington.
Charles S. Storrow,	Boston.
George F. Swain,	Boston.
William Watson,	Boston.
Morrill Wyman,	Cambridge.

CLASS II. — *Natural and Physiological Sciences.* — 57.

SECTION I. — 11.

Geology, Mineralogy, and Physics of the Globe.

Thomas T. Bouvé,	Boston.
H. Helm Clayton,	Milton.
Algernon Coolidge,	Boston.
William O. Crosby,	Boston.
William M. Davis,	Cambridge.
O. W. Huntington,	Cambridge.
Jules Marcou,	Cambridge.
William H. Niles,	Cambridge.
John E. Pillsbury,	Boston.
Nathaniel S. Shaler,	Cambridge.
Warren Upham,	Somerville.

SECTION II. — 9.

Botany.

William G. Farlow,	Cambridge.
Charles E. Faxon,	Boston.
George L. Goodale,	Cambridge.
H. H. Hunnewell,	Wellesley.
Benj. L. Robinson,	Cambridge.
Charles S. Sargent,	Brookline.
Arthur B. Seymour,	Cambridge.
Charles J. Sprague,	Boston.
Roland Thaxter,	Cambridge.

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Louis Cabot,	Brookline.
Harold C. Ernst,	Boston.
J. Walter Fewkes,	Boston.
Edw. G. Gardiner,	Boston.
Samuel Henshaw,	Cambridge.
Alpheus Hyatt,	Cambridge.
Theodore Lyman,	Brookline.
Edward L. Mark,	Cambridge.
Charles S. Minot,	Boston.
Edward S. Morse,	Salem.
James J. Putnam,	Boston.
Samuel H. Scudder,	Cambridge.
William T. Sedgwick,	Boston.
James C. White,	Boston.

SECTION IV. — 18.

Medicine and Surgery.

Samuel L. Abbot,	Boston.
Edward H. Bradford,	Boston.
Arthur T. Cabot,	Boston.
David W. Cheever,	Boston.
Benjamin E. Cotting,	Roxbury.
Frank W. Draper,	Boston.
Thomas Dwight,	Boston.
Reginald H. Fitz,	Boston.
Charles F. Folsom,	Boston.
Richard M. Hodges,	Boston.
Oliver W. Holmes,	Boston.
Frederick I. Knight,	Boston.
Francis Minot,	Boston.
Samuel J. Mixter,	Boston.
Wm. L. Richardson,	Boston.
Henry P. Walcott,	Cambridge.
John C. Warren,	Boston.
Henry W. Williams,	Boston.

CLASS III. — *Moral and Political Sciences.* — 64.

SECTION I. — 10.

Philosophy and Jurisprudence.

James B. Ames,	Cambridge.
Charles C. Everett,	Cambridge.
Horace Gray,	Boston.
John C. Gray,	Boston.
Nathaniel Holmes,	Cambridge.
John E. Hudson,	Boston.
John Lowell,	Newton.
Henry W. Paine,	Cambridge.
Josiah Royce,	Cambridge.
James B. Thayer,	Cambridge.

SECTION II. — 20.

Philology and Archæology.

William S. Appleton,	Boston.
Charles P. Bowditch,	Boston.
Lucien Carr,	Cambridge.
Franklin Carter,	Williamstown.
Joseph T. Clarke,	Boston.
Henry G. Denny,	Boston.
Epes S. Dixwell,	Cambridge.
William Everett,	Quincy.
William W. Goodwin,	Cambridge.
Henry W. Haynes,	Boston.
Bennett H. Nash,	Boston.
Frederick W. Putnam,	Cambridge.
Edward Robinson,	Boston.
F. B. Stephenson,	Boston.
Joseph H. Thayer,	Cambridge.
Crawford H. Toy,	Cambridge.
John W. White,	Cambridge.
Justin Winsor,	Cambridge.
John H. Wright,	Cambridge.
Edward J. Young,	Waltham.

SECTION III. — 21.

Political Economy and History.

Charles F. Adams,	Quincy.
Edward Atkinson,	Boston.
Edmund H. Bennett,	Boston.
Mellen Chamberlain,	Chelsea.
John Cummings,	Woburn.
Andrew M. Davis,	Cambridge.
Charles F. Dunbar,	Cambridge.
Samuel Eliot,	Boston.
A. C. Goodell, Jr.,	Salem.
Henry C. Lodge,	Nahant.
Augustus Lowell,	Boston.
Edward J. Lowell,	Boston.
Silas M. Macvane,	Cambridge.
Francis Parkman,	Boston.
John C. Ropes,	Boston.
Denman W. Ross,	Cambridge.
Charles C. Smith,	Boston.
F. W. Taussig,	Cambridge.
Henry W. Torrey,	Cambridge.
Francis A. Walker,	Boston.
Robert C. Winthrop,	Boston.

Section IV. — 13.

Literature and the Fine Arts.

Francis Bartlett,	Boston.
John Bartlett,	Cambridge.
George S. Boutwell,	Groton.
Martin Brimmer,	Boston.
J. Elliot Cabot,	Brookline.
Francis J. Child,	Cambridge.
Thos. W. Higginson,	Cambridge
S. R. Koehler,	Boston.
Charles G. Loring,	Boston.
Percival Lowell,	Brookline.
Charles Eliot Norton,	Cambridge.
Horace E. Scudder,	Cambridge.
Barrett Wendell,	Boston.

ASSOCIATE FELLOWS. — 95.

(Number limited to one hundred. Elected as vacancies occur.)

Class I. — *Mathematical and Physical Sciences.* — 36.

Section I. — 6.

Mathematics.

Fabian Franklin,	Baltimore.
Emory McClintock,	New York.
Simon Newcomb,	Washington.
H. A. Newton,	New Haven.
James E. Oliver,	Ithaca, N.Y.
J. N. Stockwell,	Cleveland, Ohio.

Section II. — 13.

Practical Astronomy and Geodesy.

Edward E. Barnard,	San José, Cal.
S. W. Burnham,	Chicago.
Geo. Davidson,	San Francisco.
Wm. H. Emory,	Washington.
Asaph Hall,	Washington.
George W. Hill,	Washington.
E. S. Holden,	San José, Cal.
James E. Keeler,	Allegany, Pa.
Sam. P. Langley,	Washington.
T. C. Mendenhall,	Washington.
William A. Rogers,	Waterville, Me.
George M. Searle,	Washington.
Chas. A. Young,	Princeton, N.J.

Section III. — 11.

Physics and Chemistry.

Carl Barus,	Washington.
J. Willard Gibbs,	New Haven.
Frank A. Gooch,	New Haven.
S. W. Johnson,	New Haven.
M. C. Lea,	Philadelphia.
J. W. Mallet,	Charlottesville, Va.
A. M. Mayer,	Hoboken, N. J.
Edward W. Morley,	Cleveland, O.
Ira Remsen,	Baltimore.
Ogden N. Rood,	New York.
H. A. Rowland,	Baltimore.

Section IV. — 6.

Technology and Engineering.

Henry L. Abbot,	New York.
Cyrus B. Comstock,	Washington.
F. R. Hutton,	New York.
Geo. S. Morison,	New York.
John Newton,	New York.
William Sellers,	Philadelphia.

Class II. — *Natural and Physiological Sciences.* — 30.

Section I. — 14.

Geology, Mineralogy, and Physics of the Globe.

Cleveland Abbe,	Washington.
George J. Brush,	New Haven.
James D. Dana,	New Haven.
Sir J.W. Dawson,	Montreal.
G. K. Gilbert,	Washington.
James Hall,	Albany, N.Y.
F. S. Holmes,	Charleston, S.C.
Clarence King,	New York.
Joseph Le Conte,	Berkeley, Cal.
J. Peter Lesley,	Philadelphia.
J. W. Powell,	Washington.
R. Pumpelly,	Newport, R.I.
Alfred R. C. Selwyn,	Ottawa.
Geo. C. Swallow,	Columbia, Mo.

SECTION II. — 3.

Botany.

A. W. Chapman,	Apalachicola, Fla.
D. C. Eaton,	New Haven.
Wm. Trelease,	St. Louis.

SECTION III. — 8.

Zoölogy and Physiology.

Joel A. Allen,	New York.
Wm K. Brooks,	Baltimore.
George B. Goode,	Washington.
O. C. Marsh,	New Haven.
H. N. Martin,	Baltimore.
S. Weir Mitchell,	Philadelphia.
A. S. Packard,	Providence.
A. E. Verrill,	New Haven.

SECTION IV. — 5.

Medicine and Surgery.

John S. Billings,	Washington.
Jacob M. Da Costa,	Philadelphia.
W. A. Hammond,	New York.
Alfred Stillé,	Philadelphia.
H. C. Wood,	Philadelphia.

CLASS III. — *Moral and Political Sciences.* — 29.

SECTION I. — 8.

Philosophy and Jurisprudence.

T. M. Cooley,	Ann Arbor, Mich.
D. R. Goodwin,	Philadelphia.
A. G. Haygood,	Oxford, Ga.
James McCosh,	Princeton, N.J.
Charles S. Peirce,	New York.
Thos. R. Pynchon,	Hartford, Conn.
E. G. Robinson,	Providence.
Jeremiah Smith,	Dover, N. H.

SECTION II. — 7.

Philology and Archæology.

A. N. Arnold,	Pawtuxet, R.I.
Timothy Dwight,	New Haven.
D. C. Gilman,	Baltimore.
A. C. Kendrick,	Rochester, N.Y.
E. E. Salisbury,	New Haven.
A. D. White,	Ithaca, N.Y.
W. D. Whitney,	New Haven.

SECTION III. — 8.

Political Economy and History.

Henry Adams,	Washington.
Geo. P. Fisher,	New Haven.
M. F. Force,	Cincinnati.
Henry C. Lea,	Philadelphia.
Edward J. Phelps,	Burlington, Vt.
W. G. Sumner,	New Haven.
J. H. Trumbull,	Hartford, Conn.
David A. Wells,	Norwich, Conn.

SECTION IV. — 6.

Literature and the Fine Arts.

James B. Angell,	Ann Arbor, Mich.
L. P. di Cesnola,	New York.
F. E. Church,	New York.
R S. Greenough,	Florence.
William W. Story,	Rome.
Wm. R. Ware,	New York.

FOREIGN HONORARY MEMBERS. — 72.

(Number limited to seventy-five. Elected as vacancies occur.)

Class I. — *Mathematical and Physical Sciences.* — 26.

Section I. — 5.

Mathematics.

Francesco Brioschi,	Milan.
Arthur Cayley,	Cambridge.
Hugo Gyldén,	Stockholm.
Charles Hermite,	Paris.
J J. Sylvester,	Oxford.

Section II. — 6.

Practical Astronomy and Geodesy.

Arthur Auwers,	Berlin.
J. H. W. Döllen,	Pulkowa.
H. A. E. A. Faye,	Paris.
William Huggins,	London.
Otto Struve,	Pulkowa.
H. C. Vogel,	Potsdam.

Section III. — 12.

Physics and Chemistry.

Adolf Baeyer,	Munich.
Marcellin Berthelot,	Paris.
R. Bunsen,	Heidelberg.
H. L. F. Helmholtz,	Berlin.
A. Kekulé,	Bonn.
Mendeleeff,	St. Petersburg.
Victor Meyer,	Heidelberg.
Marignac,	Geneva.
Lord Rayleigh,	Witham.
Sir H. E. Roscoe,	London.
Sir G. G. Stokes,	Cambridge.
Julius Thomsen,	Copenhagen.

Section IV. — 3.

Technology and Engineering.

Lord Kelvin,	Glasgow.
F. M. de Lesseps,	Paris.
Maurice Lévy,	Paris.

Class II. — *Natural and Physiological Sciences.* — 26.

Section I. — 6.

Geology, Mineralogy, and Physics of the Globe.

H. Ernst Beyrich,	Berlin.
Alfred Des Cloizeaux,	Paris.
A. E. Nordenskiöld,	Stockholm.
C. F. Rammelsberg,	Berlin.
Henry C. Sorby,	Sheffield.
Heinrich Wild,	St. Petersburg.

Section II. — 6.

Botany.

J. G. Agardh,	Lund.
Sir Joseph D. Hooker,	London.
Baron von Mueller,	Melbourne.
Julius Sachs,	Würzburg.
Marquis de Saporta,	Aix.
Eduard Strasburger,	Bonn.

SECTION III. — 10.

Zoölogy and Physiology.

P. J. Van Beneden,	Louvain.
Du Bois-Reymond,	Berlin.
L. Hermann,	Königsberg.
Thomas H. Huxley,	London.
Albrecht Kölliker,	Würzburg.
Lacaze-Duthiers,	Paris.
Rudolph Leuckart,	Leipsic.
C. F. W. Ludwig,	Leipsic.
Louis Pasteur,	Paris.
J. J. S. Steenstrup,	Copenhagen.

SECTION IV. — 4.

Medicine and Surgery.

C. E. Brown-Séquard,	Paris.
Sir Joseph Lister,	London.
Sir James Paget,	London.
Rudolph Virchow,	Berlin.

CLASS III. — *Moral and Political Sciences.* — 20.

SECTION I. — 3.

Philosophy and Jurisprudence.

James Martineau,	London.
Henry Sidgwick,	Cambridge.
Sir James F. Stephen,	London.

SECTION II. — 6.

Philology and Archæology.

Sir John Evans,	Hemel Hempstead.
Pascual de Gayangos,	Madrid.
J. W. A. Kirchhoff,	Berlin.
G. C. C. Maspero,	Paris.
Max Müller,	Oxford.
Sir H. C. Rawlinson,	London.

SECTION III. — 8.

Political Economy and History.

Duc de Broglie,	Paris.
James Bryce,	London.
Ernst Curtius,	Berlin.
W. Ewart Gladstone,	Hawarden.
Charles Merivale,	Ely.
Theodor Mommsen,	Berlin.
Jules Simon,	Paris.
Wm. Stubbs,	Oxford.

SECTION IV. — 3.

Literature and the Fine Arts.

Jean Léon Gérôme,	Paris.
John Ruskin,	Coniston.
Leslie Stephen,	London.

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